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BULLETIN 160-98

Volume 1

Public Review

DRAFT

Public Review Draft

CALIFORNIA WATER PLAN UPDATE

Bulletin 160-98

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State of California
The Resources Agency
Department of Water Resources

CALIFORNIA WATER COMMISSION

The California Water Commission serves as a policy advisory body to the Director of Water Resources on all California water resources matters. The nine-member citizen commission provides a water resources forum for the people of the State, acts as a liaison between the legislative and executive branches of State Government, and coordinates federal, state, and local water resources efforts.

ACKNOWLEDGMENT

The Department of Water Resources established an outreach advisory committee made up of people representing urban, agricultural, and environmental interests from various regions of the State to evaluate and advise DWR as to the adequacy of work in progress to update the California Water Plan.

DWR is indebted to the members of the Bulletin 160-98 Advisory Committee, who provided critical feedback on the content and analyses required to produce this California Water Plan update. While this report is a product of DWR and does not necessarily reflect the specific viewpoint of each committee member or their organization on certain issues, the Department appreciates the committee's support of the balanced approach taken to develop this water plan.

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Note to Reviewers

Here are some points to keep in mind as you read the January 1998 public review draft of Bulletin 160-98:

1. Several key documents having statewide water management significance are now circulating for public review, including the draft EIR/EIS for the CALFED Bay-Delta program, draft CVPIA Programmatic EIS, and State Water Resources Control Board draft EIR for the 1995 Bay-Delta Water Quality Control Plan. To the extent possible, we have incorporated material from these draft documents into Bulletin 160-98. However, some of our text relating to these programs is necessarily placeholder material, pending decisions about the programs' outcomes. For CALFED, for example, we have shown operations studies results for one of the alternatives, to illustrate how the program might be implemented. This placeholder material will be updated to reflect the programs' status when the final version of Bulletin 160-98 is printed.

2. SWRCB's draft EIR for the 1995 Bay-Delta Water Quality Control Plan was released just before our draft bulletin went to printing. More discussion of the EIR will be added in the final version of Bulletin 160-98. Other events occurring just as this draft was going to print include the one-year extension of the Bay-Delta Accord, release of detailed terms for San Diego - Imperial Irrigation District water transfer for public review, and Inyo County's action on the City of Los Angeles plan for dust control in Owens Valley.

3. The negotiations over California's plan to reduce its use of Colorado River water to the State's basic apportionment are continuing. Due to printing deadlines, the version of California's "4.4 Plan" described in this draft Bulletin 160-98 will lag the negotiations by about two months.

4. Numbers shown in data tables may not add due to rounding.

Chapter 1. Introduction

In 1957, the Department published Bulletin 3, the *California Water Plan.* Bulletin 3 was followed by the Bulletin 160 series, published six times between 1966 and 1993 to update the *California Water Plan.* A 1991 amendment to the California Water Code directed the Department to update the plan every five years. Bulletin 160-98 is the latest in a series of water plan updates.

The Department's Bulletin 160 series assesses California's agricultural, environmental, and urban water needs and evaluates water supplies, in order to quantify the gap between existing and forecasted future water demands and the corresponding water supplies. The report series presents a statewide overview of current water management activities, and provides water managers and others with a framework for use in making water resources decisions.

While the basic scope of the Department's water plan updates has remained unchanged over time, each plan has taken a distinct approach to water resources planning, reflecting issues or concerns at the time of its publication. For example, this update reviews in some detail the many water-related environmental restoration programs now in active implementation. On the other hand, this update does not cover nonconsumptive uses of water for hydropower generation, because there has not been significant statewide activity on this subject in recent years. (In the late 1970s/early 1980s, high energy prices and favorable tax treatment for renewable energy resources had spurred a boom in small hydropower development.) As the effects of pending utility deregulation actions become apparent, and as more Federal Energy Regulatory Commission licenses become due for renewal on major Sierra Nevada rivers, this topic may become timely for a future water plan update.

In response to public comments on the last water plan update, Bulletin 160-93, the Department has focused this 1998 update on evaluation of water management actions that could be implemented to improve water supply reliability in California. Bulletin 160-93 evaluated 2020 agricultural, environmental, and urban water demands in considerable detail. These demands, together with water supply information, have been updated for the 1998 Bulletin, which also uses a 2020 planning horizon. Much of Bulletin 160-98, however, is devoted to identification and evaluation of options for improving water supply reliability. Water management options available to, and being considered by, local agencies form the building blocks of plans prepared for each of the State's ten major hydrologic regions. (Water supplies provided by local agencies represent about 70 percent of California's developed water supplies.) These potential local options are integrated with options that are statewide in scope, such as the recommended alternative for the CALFED Bay-Delta program, to create a statewide plan.

The statewide plan represents a snapshot, at an appraisal level of detail, of how actions planned by California water managers would reduce the gap between existing supplies and forecasted future demands. The plan does not reduce all shortages statewide -- in average water years and in drought water years -- to zero in 2020. Although this goal would be an optimum solution, such an approach does not reflect economic realities and current planning by local agencies. Not all areas of the State and not all water users can afford, for instance, to reduce drought year shortages to zero. Compiling those options that appear to have a reasonable chance of being implemented by water agencies in each hydrologic region illustrates potential progress in reducing the State's future shortages.

Bulletin 160-98 estimates that California's water shortages at a 1995 level of development are 1.6 maf in average water years, and 5.2 maf in drought years. The magnitude of shortages shown for drought conditions in the base year reflect the cutbacks in supply experienced by California water users during the recent six-year drought. Bulletin 160-98 projects increased shortages by 2020 -- 2.9 maf in an average water year, and 7 maf in drought years. The future water management options identified as being most likely to be implemented could reduce those shortages to 1.4 maf in average water years and 3.9 maf in drought water years.

The accompanying sidebar summarizes key statistics developed later in the Bulletin. The material is shown here to provide the reader with an overview of California's water needs.

California -- An Overview

Figure 1-1 shows California's size relative to that of other states in the nation. California is the nation's most populous state, and is also the top-ranked state in terms of dollar value of agricultural production. Although California's present population is over 32 million people, the State still has large areas of open space and lands set aside for public use and enjoyment, including 18 national forests, 23 units of the national park system, and 355 units of the state park system. California is a state of great contrasts. Population density ranges from over 16,000 people per square mile in the City and County of San Francisco to less than 2 people per square mile in Alpine County. The highest (Mount Whitney) and lowest (Death Valley) points in the contiguous United States are located in California. The State's average annual precipitation ranges from more than 90 inches on the North Coast to about 2 inches in Death Valley.

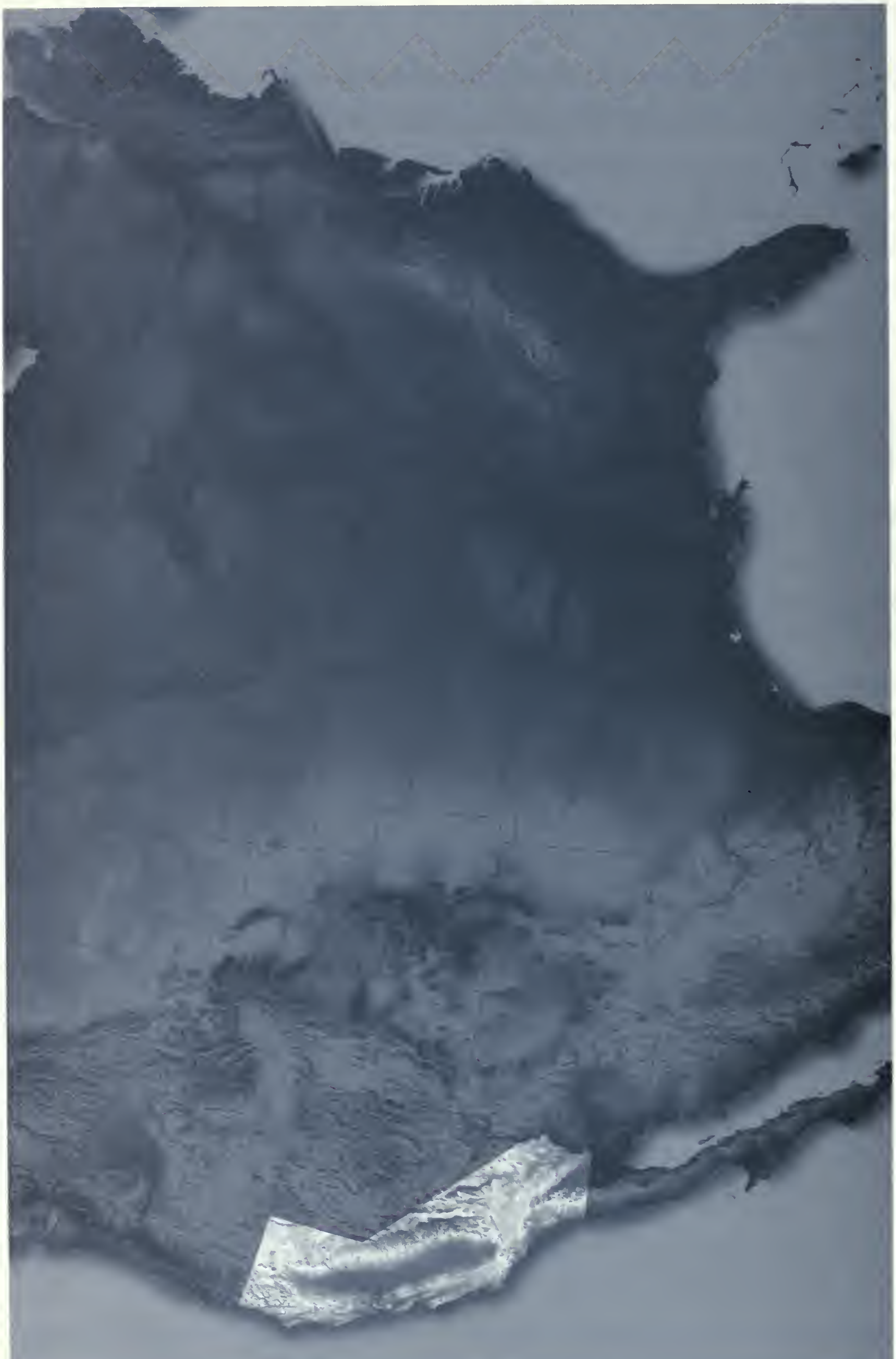
☞Photo: Half Dome at Yosemite National Park

Summary of Key Statistics

Shown below for quick reference are some key statistics presented in Chapter 4. For the water use information, values shown are for average water year conditions. The details behind the statistics are discussed later.

		Change
1995 California population	32.1 million	
2020 California population forecast	47.5 million	15.4 million
1995 California irrigated crop acreage	9.5 million acres	
2020 California irrigated crop acreage forecast	9.2 million acres	-0.3 million
1995 urban water use	8.8 maf	
2020 urban water use forecast	12.0 maf	3.4 maf
1995 agricultural water use	33.8 maf	
2020 agricultural water use forecast	31.5 maf	-2.3 maf
1995 environmental water use	36.1 maf	
2020 environmental water use forecast	37.0 maf	0.9 maf

	1995	2020	
Urban Water Use	11%	15%	4%
Agricultural Water Use	43%	39%	-4%
Environmental Water Use	46%	46%	0%
Total California Water Use	**100%**	**100%**	



The accompanying sidebar shows historic water deliveries to California's largest agricultural and urban water users. To put California's population into perspective, about one of every eight residents of the U.S. now lives in California. In the time period covered in this Bulletin (the 25 years from 1995 to 2020), California's population is forecasted to increase by more than 15 million people, an amount equivalent to adding the present populations of Arizona, Nevada, Oregon, Idaho, Wyoming, Colorado, and Utah to California. Today, four of the nation's 15 largest cities (Los Angeles, San Diego, San Jose, and San Francisco) are located in California.

California's population and abundant natural resources have helped create the State's trillion-dollar economy, which, according to the Trade and Commerce Agency, ranks seventh among world economic powers. The State's water resources have helped California be the nation's top agricultural state for 50 consecutive years. California is the nation's leading agricultural export state (and the sixth largest exporter in the world), the nation's number one dairy state, and the producer of 55 percent of the nation's fruits, nuts, and vegetables. California is the primary U.S. producer (producing more than 99 percent) of crops such as almonds, artichokes, dates, figs, kiwifruit, olives, pistachios, and walnuts. Of the top 15 agricultural counties in the U.S., ten are in California.

Figure 1-2 is a relief map of California illustrating the State's major geomorphic provinces. In roughly north to south order, our major geomorphic features are: the Klamath Mountains, Cascade Range, Modoc Plateau, Central Valley, Sierra Nevada, Coast Range, Great Basin, Transverse Ranges, Mojave Desert, Peninsular Ranges, and Colorado Desert.

California's Largest Water Retailers

Shown below are some of the largest annual retail water deliveries by local agencies, to illustrate the magnitude of urban and agricultural water demands. Retail delivery is the water supplied to an individual urban or agricultural customer. (Local agencies that wholesale water, such as Metropolitan Water District of Southern California or San Diego County Water Authority, have larger annual deliveries than the amounts shown here.)

Historic Maximum Annual Retail Water Deliveries

Water Agency	*Calendar Year*	*Delivery (af)*
Agricultural		
Imperial Irrigation District	1996	2,846,088
Westlands Irrigation District	1984	1,444,199
Glenn-Colusa Irrigation District	1984	830,500
Turlock Irrigation District	1976	686,572
Fresno Irrigation District	1995	627,000
Urban		
Los Angeles Department of Water and Power	FY 1986-87	706,000
City of San Diego	1989	256,940
East Bay Municipal Utilities District	1976	248,762
Contra Costa Water District	1988	136,864
San Jose Water Company	1987	128,439

Figure 1-2. Relief Map of California

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The Klamath Mountains are a rugged mountain range located on the California-Oregon border, through which the Klamath River has cut a deep canyon. To the east, the Cascade Range is a chain of volcanic cones that stretches from California into Washington. Until the 1980 eruption of Mount St. Helens in Washington, Mount Lassen, the southernmost of the Cascade volcanos, was the most recently active volcano in the contiguous U.S. The Modoc Plateau lies to the east of the Cascade Range, and is the southernmost part of a broad area of lava flows and small volcanic cones that covers much of eastern Oregon and southeastern Washington. The Pit River, a major Sacramento River tributary, winds through the Modoc Plateau and cuts a deep canyon through the Cascade Range, crossing that range between two of its large volcanos -- Shasta and Lassen.

☞Photo: Mount Shasta

The Central Valley is an alluvial basin about 50 miles wide by 200 miles long, bounded by the Coast Range on the west and the Sierra Nevada on the east. Except for the Tulare Lake drainage at the southern end of the valley (a closed drainage basin), rivers draining the Sierra Nevada flow onto the valley floor, join with the Sacramento or San Joaquin rivers, and flow through a gap in the Coast Range to San Francisco Bay. The Central Valley is California's most productive agricultural area, constituting about 80 percent of the State's total production. The Sierra Nevada, California's dominant mountain range, is a fault block structure whose western slopes are marked by deep river-cut canyons. Sierran rivers furnish much of California's developed surface water supplies.

☞ Photo: San Andreas Fault

The Coast Ranges are bounded on the north by the Klamath Mountains and on the south by the Transverse Ranges. The San Andreas Fault is a prominent geologic feature of the Coast Ranges; its path can readily be traced in areas where faulting has controlled the direction of watercourses such as the Gualala River. The San Andreas Fault extends into the San Bernardino Mountains of the Transverse Ranges geomorphic province (so called because these mountain ranges trend east-west). The Peninsular Ranges (which trend north-south) are a cluster of ranges separated by long valleys dividing, for example, the Riverside area from the Los Angeles coastal plain.

The western edge of the Mojave Desert is delineated by the Garlock Fault and by a portion of the San Andreas Fault. The Mojave is a region of interior drainage characterized by large areas of alluvium with scattered area of recent volcanic features. The Mojave has numerous playa lakes, including Silver Lake, the terminus of the Mojave River. The Colorado Desert to the south, also a closed drainage basin, is a lower elevation desert whose most prominent feature is the Salton Sea, which occupies a structural trough. The Basin and Range province begins on the east side of California's Sierra Nevada and extends across Nevada and into Utah. Also a region of interior drainage, it is characterized by fault block mountain ranges separated by roughly north-south trending valleys. Owens Valley and Death Valley are examples of such valleys.

☞Photo: Owens Valley

California's Water Geography

Figure 1-3 shows the location of the State's major water projects. The Central Valley Project is the largest water project in California, and the Department's State Water Project is the second largest. (Descriptions of these, and of some of the larger local water projects, are provided in Chapter 3.) There are more than 1,200 dams in California large enough to be jurisdictional under the State's dam safety program, representing about 40 maf of storage capacity. Average annual runoff within the State is about 71 maf. Unlike some other western states, the majority of California's surface water supply originates from within the State. The Colorado River is the State's largest interstate river. The accompanying sidebar highlights some statistics for California's largest waterbodies.

California Water Statistics

California's Largest Lakes and Reservoirs

Natural (Undammed) Lakes

Lake	**Storage Capacity (af)**	**Comments**
Salton Sea	7,200,000	Storage based on October 1996 water surface elevation. This is a saline lake.
Mono Lake	2,475,000	Storage based on October 1996 water surface elevation. This lake is also saline.
Eagle Lake	558,000	At water surface elevation of 5,100 feet. Has no outlet, but is a freshwater body.
Goose Lake	440,000	At water surface elevation of 4,715 feet. Partly in Oregon.

California's Largest Rivers

Based on average annual runoff

Sacramento River	22.4 maf
Klamath River	11.1 maf
San Joaquin River	6.4 maf
Eel River	6.3 maf

Based on watershed area

Sacramento River	26,548 square miles
San Joaquin River	15,946 square miles
Klamath River (California portion only)	10,020 square miles
Amargosa River (California portion only)	6,442 square miles

Figure 1-3. California's Major Water Projects

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Figure 1-4 shows how the Department subdivides the State into regions for planning purposes. The Department uses several levels of delineation. The largest is the hydrologic region, a unit used extensively in this Bulletin. California has ten hydrologic regions, corresponding to the State's major drainage basins. These regional boundaries are also used by the State Water Resources Control Board. Each of SWRCB's nine Regional Water Quality Control Boards covers one hydrologic region. (SWRCB combines the North and South Lahontan regions into one region administered by the Lahontan RWQCB.) The next level of delineation below hydrologic regions is the planning subarea. Some of the regional water management plans in Chapters 7 through 9 discuss information at the PSA level. The smallest study unit used by the Department is the detailed analysis unit, which is too small to show in Figure 1-4. California is divided into 278 DAUs. Many of the Departments' Bulletin 160 calculations are performed at the DAU level, and the results are aggregated into hydrologic regions.

Figure 1-4. California Planning Regions

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California's Hydrologic Regions

North Coast Klamath River and Lost River Basins, and all basins draining into the Pacific Ocean from the California-Oregon state line southerly through the Russian River Basin.

San Francisco Bay Basins draining into San Francisco, San Pablo, and Suisun bays, and into Sacramento River downstream from Collinsville, western Contra Costa County, and basins directly tributary to the Pacific Ocean below the Russian River watershed to the southern boundary of the Pescadero Creek Basin.

Central Coast Basins draining into the Pacific Ocean below the Pescadero Creek watershed to the southeastern boundary of Rincon Creek Basin in the western part of Ventura County.

South Coast Basins draining into the Pacific Ocean from the southeastern boundary of Rincon Creek Basin to the California-Mexico boundary.

Sacramento River Basins draining into the Sacramento River system in the Central Valley (including the Pit River drainage), from the Oregon border south through the American River drainage basin.

San Joaquin River Basins draining into the San Joaquin River system, from the Cosumnes River basin on the north through the southern boundary of the San Joaquin River watershed.

Tulare Lake The closed drainage basin at the south end of the San Joaquin Valley, south of the San Joaquin River watershed, encompassing basins draining to Kern Lakebed, Tulare Lakebed, and Buena Vista Lakebed.

North Lahontan Basins east of the Sierra Nevadan crest, and west of the Nevada stateline, from the Oregon border south to the southern boundary of the Walker River watershed.

South Lahontan The closed drainage basins east of the Sierra Nevada crest, south of the Walker River watershed, northeast of the Transverse Ranges, north of the Colorado River region. The main basins are the Owens and the Mojave river basins.

Colorado River Basins south and east of the South Coast and South Lahontan regions, areas that drain into the Colorado River, the Salton Sea, and other closed basins north of the Mexican border.

Some Trends in California Water Management Activities

The accompanying sidebar provides an overview of some key dates in California's water history. The period of the late 1940s through the 1970s was a time of significant expansion of the State's infrastructure, in response to California's post-World War II population boom. During this time, the State significantly expanded its highway system, constructed the State Water Project, and established a blueprint for an ambitious higher education system. At the federal level, many of the Central Valley Project's major facilities were constructed. There was substantial State and federal government involvement in -- and funding for -- water resources development, including direct financial assistance to local governments for constructing water supply infrastructure (e.g., Davis-Grunsky Act and Small Reclamation Projects Act programs).

The environmental movement in the latter part of the 1960s began to effect a change in society's values, resulting in a desire to preserve natural areas in an undeveloped state. With the enactment of a number of environmental protection statutes, the federal government's role in water began to shift from one of development to one of regulation. The "taxpayer revolt", typified by voter support for Proposition 13, reduced available funding to local agencies. (Two recent influences on funding sources for resources programs include deficit reduction goals for the federal budget and voter approval of Proposition 218, a measure to limit the ability of local governments to levy assessments.) There was a reduction in construction of large-scale water projects from the 1980s onward. One example of a water project caught up in changing political and social currents was water conveyance across the Sacramento-San Joaquin River Delta.

The result of these changing circumstances was that few large-scale water management actions were able to move forward. Since the lead time for large water supply projects is in the 10 to 20-year range, the consequences of inaction were not immediately felt. These consequences manifest themselves over time. California to date has been sustained by the future capacity built into the large water development projects planned in the 1950s and 1960s.

☞Photo: Bay-Delta Accord signing

A California Water Chronology

In 2000, California will celebrate its sesquicentennial (150 years of statehood). Within this relatively short (by historic standards) time period, the State's major water infrastructure and complex institutional framework for managing water have been developed. The following chronology highlights some key points in California's water history.

1848	Treaty of Guadalupe Hildago transfers California from Mexico to the U.S.
1848	Gold is discovered at Sutter's Mill on the American River.
1850	California is admitted to the Union.
1871	First reported construction of a dam on Lake Tahoe.
1884	Hydraulic mining is banned, because of its impacts on navigation and contribution to flooding.
1886	*Lux v. Haggin* addresses competing water rights doctrines of riparianism and prior appropriation.
1887	Legislature enacts Wright Irrigation District Act, allowing creation of special districts.
1887	Turlock Irrigation District becomes first irrigation district formed under the Wright Act.
1895	World's first long-distance transmission of electric power (22 miles), from a 3,000 kilowatt hydropower plant at Folsom to Sacramento.
1902	Congress enacts the Reclamation Act of 1902, creating the Reclamation Service, and authorizing federal construction of water projects.
1905	Salton Sea is created when the Colorado River breaches an irrigation canal and flows into the Salton Trough.
1913	First barrel of Los Angeles Aqueduct completed.
1914	California's present system of administering appropriative water rights is established by the Water Commission Act.
1922	Colorado River Compact signed.
1928	California Constitution amended to prohibit waste of water, and to require reasonable beneficial use.
1928	Saint Francis Dam fails
1929	State dam safety program goes into effect
1929	East Bay MUD's Mokelumne River Aqueduct is completed.
1934	San Francisco's Hetch Hetchy Aqueduct is completed.
1940	All American Canal is completed.
1941	Colorado River Aqueduct is completed.
1945	Shasta Dam is completed.
1957	DWR publishes Bulletin 3, the *California Water Plan.*
1968	Oroville Dam is completed.
1969	Legislature enacts Porter-Cologne Act, the foundation of California water quality regulatory programs.
1972	Legislature enacts California Wild and Scenic Rivers Act.
1973	California Aqueduct is completed.
1978	*California v. U.S.* held that the U.S. must obtain water rights under State law for reclamation projects, absent clear congressional direction to the contrary.
1978	SWRCB issues Decision 1485, requiring the CVP and SWP to meet specified Bay-Delta operating criteria.
1983	*National Audubon Society v. Superior Court* sets forth the application of public trust concepts to water rights administered by SWRCB.
1990	Congress enacts the Truckee-Carson-Pyramid Lake Water Rights Settlement Act (PL 101-618).
1992	Congress enacts the Central Valley Project Improvement Act (PL 102-575).
1994	SWRCB issues Decision 1631, requiring specified protections for Mono Lake levels.

In the last few years, there has been increasing recognition that all of the groups having an interest in California's water resources -- agricultural water users, environmental organizations, urban water users -- must work together in order to achieve their goals. California's hydrology, legal institutions, and water use are so sufficiently interconnected that large-scale actions cannot be successfully implemented without some degree of consensus. Nowhere has this been more apparent than in the Delta, the hub of much of California's water supply. Signing of the Bay-Delta Accord in 1994 created the circumstances under which CALFED's Bay-Delta program could develop a proposed solution to Delta environmental restoration and water supply needs. The approach taken in the Bay-Delta embodies some hallmarks of today's water management activities -- increased participation by local governments and other stakeholders in water management issues of statewide scope, and significant efforts to carry out ecosystem restoration actions.

Greater local government and other stakeholder participation in statewide-level water management decision-making is an emerging trend. Examples include the CALFED process for a long-term Bay-Delta solution and stakeholder negotiating forums occurring in response to the State Water Resources Control Board's water rights process for the Bay-Delta. Examples outside the Delta include the State Water Project's Monterey Agreement contract amendments.

Formal governance structures are being employed to coordinate and manage the collective actions of local agencies. For example, CVP water users formed three joint powers authorities to contract with USBR for operation and maintenance of CVP facilities. Those JPAs have been working with USBR to develop mechanisms to allow the JPAs to finance normal O&M activities themselves, rather than having to go through the congressional appropriations process. Another JPA has been formed by two county governments and two water agencies to implement Salton Sea restoration actions.

In terms of water management programs themselves, a theme dominating much water management planning at the statewide level is ecosystem restoration (accompanied by substantial funding). Bay-Delta actions are an example of this trend -- voter approval of Proposition 204 provided $460 million for State restoration actions directly associated with the Delta, and another $93 million in State matching funds for USBR's CVPIA restoration actions. USBR's annual budget for CVPIA restoration actions covered by the Restoration Fund has been in the $40 million range. Other examples of funding for environmental restoration actions are described later in this Bulletin.

One emerging trend is increased reliance on water transfers, especially in average water years. For example, a cursory review of water agencies' plans for transfers (including transfers for environmental purposes) showed that plans of some larger water agencies amounted to at least 1 maf of transfers in average water years, and 1.8 maf in drought water years. (To put these figures into perspective, the maximum allocated yield of the Department's Drought Water Bank in 1991 was about 390 taf, although the DWB purchased over 800 taf.) Although many successful water transfers have been carried out in California, there remain issues to be worked through for larger transfers, particularly for those involving complex subjects such as third-party impacts or groundwater substitution.

Changes Since the Last *California Water Plan* Update

The last *California Water Plan* update, Bulletin 160-93, was published in 1994. At that time, California had recently emerged from the six-year drought and Bay-Delta issues were in a state of flux (the Bay-Delta Accord had not yet been signed). As we publish Bulletin 160-98, California has just weathered the most damaging flood event in history, and new (interim) Bay-Delta standards are in place. As discussed above, major ecosystem restoration actions are now underway for the Delta.

Changes in Delta conditions are a difference between the two Bulletins. Bulletin 160-93 was based on SWRCB D-1485 regulatory conditions in the Delta, and used a range of 1 to 3 maf for future environmental water needs, reflecting uncertainties associated with Bay-Delta water needs and Endangered Species Act implementation. Bulletin 160-98 uses SWRCB's Order WR 95-6 as the base condition for Bay-Delta operations, and addresses the proposed CALFED actions for the Bay-Delta.

Bulletin 160-93 was the first water plan update to examine the demand/supply balance for drought water years as well as for average water years. This approach, a response to water shortages experienced during the recent drought, has since been adopted for planning purposes by many local agencies. Bulletin 160-98 retains the drought analysis, but also considers the other end of the hydrologic spectrum -- flooding. Traditionally, water supply has been the dominant focus of the water plan updates. In the aftermath of the devastating January 1997 flooding in Northern and Central California, common areas in water supply and flood control planning and operations have been highlighted, and benefits of multipurpose facilities have been emphasized.

Other changes between the two reports resulted from public comments on Bulletin 160-93. The dominant public comment on the last Bulletin was that it should show a plan for reducing the gap between existing supplies and forecasted future demands, in addition to making supply and demand forecasts. Bulletin 160-98 addresses that comment by presenting a compilation of local agencies' planning efforts together with potential water management options that are statewide in scope. Local agencies' plans form the base for this effort, since it is local water purveyors who have the ultimate responsibility for meeting their service area's needs. About 70 percent of California's developed water supply is provided by local agencies.

Another change, in response to public comments, was the treatment of groundwater overdraft as a shortage in the Bulletin's base year. Bulletin 160-98 is the first water plan update to show an average water year shortage in its base year (1995). About 1.5 maf of the 1.6 maf shortage is attributable to groundwater overdraft.

Also, Bulletin 160-98 uses applied water data, rather than the net water amounts historically used in the water plan series. This change was made in response to public comments that net water data were more difficult to understand than applied water data. This concept is explained in Chapter 4.

Differences in Demand/Supply Balances

Bulletin 160-93 used a planning period of 1990-2020. Bulletin 160-98 uses a planning period of 1995-2020. Bulletin 160-98 uses the same 2020 planning horizon as did the previous Bulletin because no major new data were generated in the interim between the two reports that would justify extending the planning horizon. Urban water demands depend heavily on population forecasts, and the next U.S. Census will not be conducted until 2000.

Table 1-1 compares some key figures from the two Bulletins, for average water years. In order to compare the net water figures used in Bulletin 160-93 with the applied water amounts shown in Bulletin 160-98, the Bulletin 160-93 numbers were converted to applied water amounts.

Table 1-1. 2020 Average Year Forecasts

	Bulletin 160-93	*Bulletin 160-98*
population	48.9 million	47.5 million
irrigated crop acreage	9.3 million acres	9.2 million acres
urban water use	12.7 maf	12.0 maf
agricultural water use	28.8 maf	31.5 maf
environmental water use	29.3 maf	37.0 maf
average water shortage	3.7 to 5.7 maf	2.9 maf

The water plan series uses Department of Finance population forecasts. DOF reduced its 2020 forecast for California in the time period between Bulletin 160-93 and Bulletin 160-98. The reduction reflects the impacts of the economic recession in California in the early 1990s. California experienced a record negative net domestic migration then, as more people moved out of the State than moved in. This reduction in the population forecast translates to a reduction in forecasted urban water use in Bulletin 160-98.

The 2020 agricultural water use forecast increased from Bulletin 160-93 to Bulletin 160-98, even though the forecasted crop acreage decreased slightly. This increase resulted from the elimination of the "other" category of water use shown in Bulletin 160-93, which included conveyance losses. For Bulletin 160-98, water in the "other" category was reallocated back to the major water use categories to simplify information presentation. Most of the conveyance losses are associated with agricultural water use. Combining the "other" category into the major water use categories affected the agricultural water use forecast the most.

The 2020 environmental water use forecast increased from Bulletin 160-93 to Bulletin 160-98, reflecting implementation of the Bay-Delta Accord and some new instream flow increases, and forecasted future demands for CVPIA supplemental fishery water and Level 4 wildlife refuge water.

The shortages shown in Bulletin 160-98 are of similar magnitude to the low end of the shortage ranges used in Bulletin 160-93. The range of potential future environmental water needs of 1 to 3 maf used in Bulletin 160-93 was arithmetically added to the base of that Bulletin's environmental water use forecast, rather than being evaluated through operations studies, because

Bay-Delta regulatory assumptions could not be determined then. This conservative approach yielded higher demands than operations studies would have provided. For this reason, the Bulletin 160-93 demands were higher.

Works in Progress

As this public review draft of Bulletin 160-98 is being prepared, there are several pending water management issues that could be characterized as works in progress, and whose outcome will have a near-term impact. This is a busy time in the world of California water, as indicated by the sidebar showing draft documents now in some stage of review. The note to reviewers bound at this front of the Bulletin, highlights the major activities (e.g., CALFED Bay-Delta program, Colorado River negotiations) for which the Bulletin uses placeholder text. This text will be updated to reflect the status of those activities when the final version of Bulletin 160-98 is printed.

There are uncertainties associated with the possible outcomes of these works in progress, just as there are with any process that is evaluated in mid-course. For example, the impact of disagreements over management of CVPIA dedicated water (the 800 taf of water dedicated by CVPIA for environmental purposes) on the larger CALFED Bay-Delta program is one uncertainty. Other uncertainties include the outcome of SWRCB's Bay-Delta water rights proceeding and the reaction of other Colorado River Basin states to California's proposed plan to reduce its use of Colorado River water. Probably an apt summation of attempts to predict the outcomes of these uncertainties is the quotation from Dickens' *Tale of Two Cities* that "It was the best of times, it was the worst of times, . . . we had everything before us, we had nothing before us".

Colorado River interstate issues are a new addition to a statewide water picture largely dominated by Delta and CVPIA issues in the recent past. Achieving a solution to California's need to reduce its use of Colorado River water to the State's basic apportionment (a reduction of as much as 900 taf from historic uses) would require consensus among California's local agencies that use the river's water, as well as concurrence in the plan by the other basin states. The area of the State facing the bulk of the shortages from a reduction in Colorado River water use is urbanized Southern California, an area that also depends on exports from the Delta. The plan being prepared by California's Colorado River Board would help alleviate the South Coast

Region's shortages by conservation and transfers from agricultural users of Colorado River water.

The Colorado River shortages facing Southern California are symptomatic of the need for water purveyors throughout the State to move forward in finding solutions to California's future water needs, and especially to future drought year water needs. Local water agencies' increasing participation in statewide water management activities and greater emphasis in solving problems at a regional or watershed level are positive steps toward finding solutions to our future water needs.

Documents Now in Public Review

Readers of this public review draft may feel overwhelmed by the sheer volume of water-related material of statewide significance that is now at some stage of a public review process. Some of the major documents out for review include:

Document	Author
Public review draft, Bulletin 160-98	Department of Water Resources
CVPIA draft programmatic EIS	USBR and USFWS
Draft program EIR/EIS for Bay-Delta	CALFED
Draft EIR on implementation of 1995 Water Quality Control Plan for the Bay-Delta	SWRCB
Revised draft, Anadromous Fish Restoration Program (May 1997 draft)	USFWS and USBR

Organization of Bulletin 160-98

Immediately following this introductory chapter is an overview of recent events in California water (Chapter 2). Chapter 2 summarizes significant changes in statutes and programs since the publication of Bulletin 160-93. An appendix for Chapter 2 (all appendices are bound together at the end of the draft bulletin) summarizes some of the major State and federal statutes dealing with water. Chapters 3 and 4 cover California water supplies and water demands. Chapter 5 describes the status of technology applications relating to water supply, reflecting the continuing public interest in topics such as potential future use of seawater desalting. Chapter 5 also provides an overview of fish screening technology applications.

Chapters 6 through 9 focus on plans to meet California's future water needs. Chapter 6 covers water management actions that would be applicable at a statewide level, including actions such as the CALFED Bay-Delta program, State Water Project future water supply options, and CVPIA fish and wildlife water acquisition. Chapters 7 through 9 contain regional water management plans for each of the State's ten major hydrologic regions. These regional plans are combined in Chapter 10 into a tabulation of actions most likely to be taken to meet California's future water needs. The water budget tables in Chapter 10, shown for a 2020 level of demand with and without future water management options, are the key results of the Bulletin's planning process.

Following Chapter 10 are a brief glossary and list of acronyms, and technical appendices.

Chapter 2. Recent Events in California Water

This chapter highlights some significant infrastructure and institutional changes that have occurred since the publication of Bulletin 160-93, and reviews the status of selected high-profile programs. In one sense, this chapter helps illustrate some success stories in California water management, and responds to the general public's often-asked question of "What is being accomplished to help meet California's future water needs?"

Infrastructure Update

A common theme in previous editions of the California Water Plan has been the need to respond to California's continually increasing population. Population growth brings with it the need for new or expanded infrastructure. This section provides a very brief overview of the most significant infrastructure projects which are now under construction or have been completed recently. Some of these projects are described in more detail in later chapters.

The most significant large dams under construction in California are listed in Table 2-1. Significantly, both water supply projects are offstream storage facilities, demonstrating that offstream facilities have a greater likelihood of successfully completing environmental permitting processes than on-stream facilities.

Table 2-1. Large Dams Under Construction in California

Dam	*Constructing Agency*	*Reservoir Capacity*	*Purpose*	*Estimated Project Cost*[1]
Seven Oaks	USACE	146 taf	flood control	$366 million
Los Vasqueros	CCWD[2]	100 taf	offstream storage	$450 million
Eastside	MWD[3]	800 taf	offstream storage	$2 billion

1. Project construction costs include costs for land acquisition, environmental mitigation, and associated facilities (such as pipelines and road relocations).
2. CCWD = Contra Costa Water District
3. MWD = Metropolitan Water District of Southern California

The most significant large conveyance projects that are under construction or have been recently completed are shown in Table 2-2. As with the offstream storage reservoirs, these conveyance facilities do not by themselves develop new water supply, but allow existing supplies to be transported to new service areas, or a more efficient use of existing supplies.

Table 2-2. Major Water Conveyance Facilities Since 1992

Facility	*Constructing Agency*	*Status*	*Length*	*Max. Cap.*
Coastal Branch Aqueduct Extension (Phase II)	DWR	1997 comp.	102 mi.	65 cfs 47,816 af/yr
Eastside Reservoir Pipeline	MWDSC	1997 comp.	8 mi.	1,000 cfs
East Branch Enlargement	DWR	1996 comp.	100 mi.	2,880 cfs
Mojave River Pipeline	MWA[1]	1997 start	70 mi.	94 cfs 55,900 af/yr
East Branch Extension	DWR	1998 start	14 mi. new 33 mi. total	104 cfs
Inland Feeder Project	MWDSC	1997 start	44 mi.	1,000 cfs
Morongo Basin Pipeline	MWA	1994 comp.	71 mi.	14,500 af/yr
New Melones Water Conveyance Project	SEWD[2] and CSJWCD[3]	1993 comp.	21 mi.	500 cfs

1. MWA = Mojave Water Agency
2. SEWD = Stockton East Water District
3. CSJWCD = Central San Joaquin Water Conservation District

☞Photo: Coastal Aqueduct construction.

Tables 2-3 and 2-4 show a few of the largest or most recent desalting and water recycling facilities. These projects are typically much smaller in size than the storage and conveyance projects highlighted above, and generally supply a local service area.

Table 2-3. Desalting Plants

Plant	Owner	Capacity[1]	Comments
Brackish Water Desalting			
Arlington	Santa Ana Watershed Project Authority	6 mgd	Operational
Oceanside	city of Oceanside	2 mgd	Operational, being expanded
Tustin	city of Tustin	3 mgd	Operational
West Basin	West Basin MWD	1.5 mgd	Operational
Wastewater Desalting			
Water Factory 21	OCWD[2]	5 mgd	Operational, being expanded
West Basin	West Basin MWD	5 mgd	Operational, being expanded to 7.5 mgd
San Diego	city of San Diego	18 mgd	Pilot testing underway, with 1 MGD unit
Seawater Desalting			
Santa Barbara	city of Santa Barbara	6.7 mgd	Standby as drought reserve
Santa Catalina Island	SCE[3]	0.1 mgd	Operational
Morro Bay	city of Morro Bay	0.6 mgd	Periodic Update (last 6/95)
Marina	Marina Coast Water District	0.3 mgd	Operational

1 One mgd equals 1,120 af per year
2 OCWD = Orange County Water District
3 SCE = Southern California Edison

Table 2-4. Water Reclamation Plants

Plant	Owner	Capacity (mgd)	Comments
West Basin Water Recycling Facility	West Basin Water District	37.0	Expansion completed late 1997; industrial use, landscape irrigation, and seawater intrusion barrier
North City Water Reclamation Plant	city of San Diego	30.0	Expansion to 30 mgd completed 9/97. Effluent from this plant may be used as influent to the proposed San Diego Repurification Plant
Terminal Island Treatment Plant	city of Los Angeles	30.0	Reclamation facility is expected to be operational by 1999; 17 mgd is slated for seawater intrusion barrier
Salinas Valley Reclamation Plant	Monterey Regional Water Pollution Control Agency	29.6	Completed 9/97; food crop irrigation
City of Bakersfield WWTP No. 2	city of Bakersfield	19.0	Operational in 1995; agricultural irrigation
City of Bakersfield WWTP No. 3	city of Bakersfield	12.0	Operational in 1995; agricultural irrigation
Water Factory 21	Orange County Water District	10.0	Seawater intrusion barrier
City of Barstow Water Reclamation Plant	city of Barstow	9.0	Operational in 1995; seven irrigation groundwater recharge
City of Burbank Water Reclamation Facility	city of Burbank	9.0	Operational in 1995; golf course irrigation
Camarillo Sanitation District WRF	Camarillo Sanitation District	6.8	Operational in 1995; agricultural irrigation
City of Escondido Water Reclamation Plant	city of Escondido	6.0	Construction of secondary facilities ongoing; tertiary and distribution facilities operational by 2002
Pebble Beach CSD Reclamation Plant	Carmel Area Wastewater District	5.8	Latest expansion completed in 1995; landscape irrigation
North Richmond Water Reclamation Plant	East Bay Municipal Utility District	5.4	Operational in 1995; industrial cooling water
Padre Dam PUD Water Recycling Facility	Padre Dam Public Utility District	2.0	Operational in 1995; landscape irrigation

Table 2-5 shows some recently completed structural environmental restoration actions, or those under construction. Projects listed in this table represent some of the largest examples of restoration actions; a number of small fish screening and spawning gravel replenishment projects have also been carried out. In addition to the projects shown in the table, there are a number of larger fish screening projects on the Sacramento River system that are expected to begin construction in the summer of 1998. Projects beginning construction then will be added to Table 2-5 when the public draft of the Bulletin is finalized.

Table 2-6 shows a sampling of completed smaller restoration projects, many of them dealing with spawning habitat enhancement, funded by the State Water Project's 4-Pumps program (described in Chapter 6).

Table 2-5. Major Fishery Restoration Projects

Project	Owner	Description
Shasta Dam Temperature Control Device	USBR	An approximately $83 million modification to the dam's outlet works to allow temperature-selective releases of water through the dam's powerplant
Red Bluff Diversion Dam Research Pumping Plant	USBR	A $40 million experimental facility to evaluate fishery impacts of different types of pumps used to divert Sacramento River water into the Tehama-Colusa and Corning Canals
Butte Creek fish passage	Western Canal Water District	A multi-component project to improve fish passage by removing small irrigation diversion dams from the creek. During 1997-98, the district is removing two diversion dams and replacing them with a siphon under the creek. Funding for this approximately $10 million component is being provided by the district, CVPIA's anadromous fish restoration program, and CALFED's Category III program.
Parrot-Phelan Dam Fish Ladder	M&T Ranch	Funds from the Wildlife Conservation Board and CVPIA's AFRP were used to build a pool and chute fish ladder at this privately-owned site on Butte Creek. The approximately $800,000 fish ladder replaced a poorly performing ladder at the same site.

Table 2-6. Sample Restoration Projects Funded in Part by the SWP's 4-Pumps Program

Location	Description	Implementing Agency(s)	Capital Costs	Completion Date
Suisun Marsh Fish Screening Project				
Suisun Marsh	Design, construct, and install seven fish screens on diversions to managed wetlands within Suisun Marsh.	SRCD, DFG, DWR, USBR	$2 million	6 of 7 screens will be installed October 1997
Deer Creek Water Exchange Project				
Upper Sacramento River watershed, Deer Creek	Construct up to 9 wells and improve water transport facilities for Deer Creek Irrigation District and Stanford Vina Ranch Irrigation Company to replace diversions (up to 50 cfs) bypassed to provide flows for spring-run and fall-run chinook salmon and steelhead.	DWR, DFG, DCID, SVRIC	$1,650,000	Construction scheduled to begin Fall 1997 and to be completed in FY 98/99.
Parrot-Phelan Fish Ladder, Butte Creek				
Butte Creek at Parrot-Phelan Dam, east of Chico	Design and construct a pool-chute fish ladder to provide fish passage.	DFG, USBR, DWR	$800,000	Fall 1995
Durham Mutual Fish Screens and Ladder, Butte Creek				
Butte Creek at Durham Mutual Dam, east of Chico	Install two fish screens and an improved high volume fish ladder to eliminate entrainment and improve fish passage	Durham Mutual Water Company, USBR, Category III, DWR, DFG	$930,000	Summer-Fall 1998
Magneson Salmon Habitat Restoration and Predator Habitat Isolation Project, Merced River				
Merced River (River Mile 29-30)	Restore river channel and isolate abandoned gravel pit.	DFG, DWR	$336,000	September 1996
M.J. Ruddy Spawning Habitat Project, Tuolumne River				
Tuolumne River about 4 miles upstream of Waterford	Restore stream channel and floodplain to provide gravel recruitment.	DFG, DWR	$316,000	July 1993
Stanislaus River Spawning Habitat Restoration, 3 Riffles (River Mile 47.4, 50.4, and 50.9)				
Stanislaus River	Restore salmon spawning gravel at three sites.	DFG, DWR	$209,000	September 1994

Legislative Update

This section summarizes recent (within the last five years) major changes to State and federal statutes affecting water resources management. The existing statutory and regulatory framework for California water management is summarized in Appendix 2A.

State Statutes

Local Water Supply Reliability. In 1995, the Legislature chaptered three bills dealing with water supply reliability and long-range planning to serve future water needs. Two of the bills [Statutes of 1995, Chapters 330 and 854] amend existing requirements for preparing urban water management plans, by requiring that local agencies make a specified assessment of the reliability of their water supplies. (Water agencies serving more than 3,000 customers or 3,000 acre-feet annually are required to prepare urban water management plans and to update the plans at least every five years.) Local water agencies are required to evaluate the reliability of their supplies in varying water year types (normal, dry, and critically dry). The third bill [Statutes of 1995, Chapter 881] requires that cities and counties making specified land use planning decisions, such as amending a general plan, consult with local water agencies to determine if water supply is available. The bill also requires that findings by the local water agencies on water supply availability be incorporated into cities or counties environmental documentation for the proposed action.

Financing Water Programs and Environmental Restoration Programs. *Proposition 204.* In November 1996, California voters passed Proposition 204--the Safe, Clean, Reliable Water Supply Act. The Act authorizes the issuance of $995 million in general obligation bonds to finance water and environmental restoration programs throughout the state. Approximately $600 million of these bonds provides the State share of costs for projects to benefit the Bay-Delta and its watershed. Three hundred ninety million dollars of this amount is to implement CALFED's ecosystem restoration program for the Bay-Delta. These funds would be available after a final federal and State environmental impact study/report is certified and a cost share agreement is executed between the federal and State governments for eligible projects. Table 2-7 summarizes programs authorized for Proposition 204 funding.

Table 2-7. Proposition 204 Funding Breakdown

Program	Dollars (in millions)
Delta Restoration ($193 million)	
CVPIA State share	$93
Category III State share	60
Delta levee rehabilitation	25
South Delta barriers	10
Delta recreation	2
CALFED Administration	3
Clean Water and Water Recycling ($235 million)	
State Revolving Fund Clean Water Act loans	80
Clean Water Grants to small communities	30
Loans for water recycling projects	60
Loans for drainage treatment and management projects	30
Delta tributary watershed rehabilitation grants and loans	15
Seawater intrusion loans	10
Lake Tahoe water quality improvements	10
Water Supply Reliability ($117 million)	
Feasibility investigations for specified programs	10
Water conservation and groundwater recharge loans	30
Small water project loans and grants, rural counties	25
Sacramento Valley Water Management and habitat improvement	25
River parkway program	27
CALFED Bay-Delta Ecosystem Restoration Program	**390**
Flood Control Subventions	**60**
TOTAL	**$ 995**

Proposition 218. Voter approval of Proposition 218 in November 1996 changed the procedure used by local government agencies for increasing fees, charges, and benefit assessments; benefit assessments, fees and charges that are imposed as an "incident of property ownership" are subject to a majority public vote. Proposition 218 defines "assessments" as any levy or charge on real property for a special benefit conferred to the real property, including special assessments, benefit assessments, and maintenance assessments. Proposition 218 further defines "fee" or "charge" as any levy (other than an ad valorem tax, special tax, or assessment), which is imposed by an agency upon a parcel or upon a person as an incident of property ownership, including a user fee or charge for a property-related service.

Although there are many tests to determine if a fee or charge is subject to the provisions of Proposition 218, the most significant one is whether or not the agency has relied upon any parcel map for the imposition of the fee or charge. As with most new legislation, there is uncertainty in the interpretation of its requirements, especially as they relate to certain water-related fees and charges. From one point of view, Proposition 218 could be interpreted as a comprehensive approach to regulate all forms of agency revenue sources, and this broad interpretation would include all fees and charges for services provided to real property. Types of water-related charges and fees that may be affected by Proposition 218's requirements include meter charges, acreage-based irrigation charges, and standby charges. It is expected that additional legislation or other judicial interpretation will be needed to clarify the application of Proposition 218 to the types of fees and charges used by water agencies. Some possible implications of the proposition for water-related fees and charges include:

- Water service charges often include a monthly or bi-monthly meter charge which is a fixed amount payable whether or not any water is used. Since they are usually based upon the size of the meter or type of building and are not related to the property, they are probably not affected by Proposition 218.
- Many irrigation districts levy charges based upon the acreage of the property. For some of these districts, the charges are solely based upon the amount of acres irrigated with the water supplies and not the amount of water used. In these situations, acreage-based charges are likely to be subject to the provisions of Proposition 218. However, if the charges are based upon actual or estimated water use, then they are less likely to be subject to Proposition 218.
- Standby charges are classified as assessments by Proposition 218 and are subject to its provisions.

To date, there has been one water-related legislative clarification of Proposition 218 subsequent to its enactment by the voters. A 1997 statute clarified that assessments imposed by water districts and earmarked for bond repayment are not subject to the voter approval requirements of the proposition.

Water Recycling. In 1995, legislation amended statutes in the Water Code, Fish and Game Code, Health and Safety Code, and elsewhere, to replace terms such as wastewater "reclamation" or "reclaimed water" with water "recycling" or "recycled water." The legislation was sponsored by wastewater recycling proponents, who were seeking terminology that would enhance public acceptance of recycled water supplies.

MTBE. Detection of methyl tertiary butyl ether in water supplies soon after the compound's approval for use as an air pollution-reducing additive in gasoline has raised concerns about its mobility in the environment. Legislation enacted in 1997 included several provisions dealing with MTBE regulation, monitoring, and studies. One provision requires the Department of Health Services to establish a primary (health-based) drinking water standard for MTBE by July 1999, and secondary (taste and odor) drinking water standard by July 1998. (MTBE can be detected by taste at very low concentrations; hence the early requirement for a secondary drinking water standard.)

Federal Statutes

Safe Drinking Water Act. The Safe Drinking Water Act, administered by EPA in coordination with the states, is the chief federal regulatory legislation dealing with drinking water quality. The 104th Congress reauthorized and made significant changes to the SDWA, which had last been reauthorized in 1986. Major changes include:

- Establishment of a drinking water state revolving loan fund, to be administered by states in manner similar to the existing Clean Water Act State Revolving Fund. Loans would be made available to public water systems to help them comply with national primary drinking water regulations and upgrade water treatment systems.
- The standard-setting process for drinking water contaminants established in the 1986 amendments was changed from a requirement that EPA adopt standards for a set number of contaminants on a fixed schedule to a process based on risk assessment and cost/benefit analysis. The 1996 amendments require EPA to publish (and periodically update) a list of contaminants not currently subject to NPDRWs, and to periodically determine whether to regulate at least five contaminants from that list, based on risk and benefit considerations.
- A requirement that states conduct vulnerability assessments in priority source water areas expanded the existing source water quality protection provisions. States are authorized to

establish voluntary, incentive-based source protection partnerships with local agencies. This activity may be funded from the new SRF.

- As a result of the 1996 amendments, EPA has adopted a more ambitious schedule for promulgating the Disinfectants/Disinfection By-Products Rule and the Enhanced Surface Water Treatment Rule. The first phase of the D/DBP Rule is proposed to take effect in late 1998, as is an interim ESWTR. More stringent versions of both rules are proposed to follow in 2002. This subject is discussed in more detail in Chapter 3.

Clean Water Act Reauthorization. The Clean Water Act, administered by EPA in coordination with the states, is the chief federal regulatory statute controlling point and nonpoint source discharges to surface water. The CWA additionally provides federal authority for wetlands protection and regulation of dredging and filling activities affecting waters of the United States. CWA reauthorization proposals were heard in the 103rd and 104th Congresses, but no legislation was enacted. The act's broad scope complicates reauthorization.

Some of the topics covered in reauthorization proposals have included funding levels for the SRF program; changes to the water quality standard setting process (such as special recognition of the wildlife/fishery benefits of discharge of reclaimed water to streams in arid areas which would otherwise not be able to support a fishery); recognition of the impacts of introduced aquatic species on species of concern in the water quality standard setting process; Good Samaritan liability provisions for remediation measures at abandoned mines; new programs for nonpoint source management and regulation of combined sanitary/stormwater sewers; new stormwater management requirements for municipalities; recognition of state primacy in water quantity allocation; and expanded statutory treatment of wetlands protection requirements.

Endangered Species Act Reauthorization. As with the CWA, ESA reauthorization proposals were heard in past congresses, but no legislation has been enacted. Some of the proposed changes included amending the act to focus on preserving ecological communities rather than a single-species or subspecies focus, providing for stakeholder participation and peer-reviewed science in the species listing process, addressing management of candidate species, streamlining the Section 7 consultation process, quantifying recovery plan objectives, and providing assurances and regulatory relief for nonfederal landowners.

Reclamation, Recycling, and Water Conservation Act of 1996. This act amends Title 16 of PL 102-575 by authorizing federal cost-sharing in additional wastewater recycling projects. (PL 102-575 had authorized federal cost-sharing in specified recycling projects.) The additional California projects are shown below, along with the nonfederal sponsors identified in the statute.

- North San Diego County area water recycling project (San Elijo Joint Powers Authority, Leucadia County Water District, city of Carlsbad, Olivenhain Municipal Water District)
- Calleguas Municipal Water District recycling project (District)
- Watsonville area water recycling project (city of Watsonville)
- Pasadena reclaimed water project (city of Pasadena)
- Phase 1 of the Orange County regional water reclamation project (Orange County Water District)
- Hi-Desert Water District wastewater collection and reuse facility (District)
- Mission Basin brackish groundwater desalting demonstration project (city of Oceanside)
- Effluent treatment for the Sanitation Districts of Los Angeles County with the city of Long Beach (Water Replenishment District of Southern California, Orange County Water District)
- San Joaquin area water recycling and reuse project (San Joaquin County, city of Tracy)

Federal cost-sharing in these projects is authorized at a maximum of 25 percent for project construction, and federal contributions for each project are capped at $20 million. Funds are not to be appropriated for project construction until after a project feasibility study and a cost-sharing agreement are completed. In addition, federal cost-sharing may not be used for operations and maintenance.

The act also authorizes the Department of the Interior to cost-share up to 50 percent (planning and design) in the Long Beach desalination research and development project. Local sponsors are the city of Long Beach, Central Basin Municipal Water District, and MWD.

Water Desalination Act of 1996. This act authorizes DOI to cost share in non-federal desalting projects at levels of 25 percent or 50 percent (for projects which are not otherwise feasible unless a federal contribution is provided). Cost-shared actions can be research, studies, demonstration projects, or development projects. The authorization provides $5 million per year for fiscal years 1997 through 2002 for research and studies, and $25 million per year for the same period for demonstration and development projects. The act requires DOI to investigate at least three different types of desalting technology, and to report research findings to Congress.

National Invasive Species Act of 1996 (PL 104-332). NISA reauthorized and amended the Nonindigenous Aquatic Nuisance and Prevention and Control Act of 1990. The purpose of the legislation was to provide tools for the management and control of the spread of aquatic nuisance species, such as zebra mussels. NISA reauthorized a mandatory ballast management program for the Great Lakes, an area already heavily infested with zebra mussels, and created an enforceable national ballast management program for all U.S. coastal regions. The act requires detailed reporting on ballast exchange by cargo vessels. Ship ballast water has been identified as a likely mode of introduction for many of the nonindigenous invertebrates identified in San Francisco Bay-Delta, now home to at least 150 introduced plant and animal species.

☞Photo: zebra mussel

Federal and State Programmatic Actions

State Water Project Monterey Agreement Contract Amendments

The Monterey Agreement between DWR and SWP water contractors was signed in December 1994. This agreement set forth principles for making changes in the contractors' SWP water supply contracts which would then be implemented by an amendment, known as the Monterey Amendment, to each contractor's SWP contract. The Amendment has been offered to all SWP contractors. Those contractors that sign the Amendment will receive the benefits of it, while those that do not will have their water supply contracts administered such that they will be unaffected by the Amendment. As of December 1997, 26 of the 29 contractors had signed the Monterey Amendment.

In general, the Monterey Amendment provides a new array of water management tools to the water contractors. More specifically, the Amendment changes the rules for water allocations, provides for permanent transfer of a portion of contract water supply entitlement and the Kern Water Bank property, provides operational flexibility for use of SWP facilities, and allows some financial restructuring for the SWP.

Clarification of SWP Water Allocation Rules. The Amendment stated that, during water-short years, project supplies would be allocated proportionately on the basis of contractors' entitlements. In addition, the Amendment allocates water on an equal basis to urban and agricultural purposes, deleting the previous initial supply reduction to agricultural contractors.

Permanent Sales of Entitlement. The Amendment provides for transfer of up to 175,000 acre-feet of entitlement away from agricultural use. The first transfer made was the relinquishing of 45,000 acre-feet of entitlement (40,670 acre-feet from Kern County Water Agency, 4,330 acre-feet from Dudley Ridge Water District) back to the SWP. This relinquishment reduces the total SWP entitlement commitment. In addition, the Amendment provides an additional 130,000 acre-feet of agricultural entitlements to be sold on a permanent basis to urban contractors (on a willing buyer-willing seller basis). As of April 1997, 25,000 acre-feet of Kern County Water Agency entitlement had been purchased by Mojave Water Agency for recharge in Mojave's groundwater basin. In addition, some 9,000 acre-feet per year of KCWA entitlement was in the process of being permanently transferred to Castaic Lake Water Agency. Other potential permanent transfers are being discussed.

Storing Water Outside a Contractor's Service Area; Transfers of Non-Project Water. While some of the Amendment's benefits help the larger SWP contractors, the ability to store water outside a contractor's service area either directly or through exchanges is a significant benefit to the smaller contractors as well. Many SWP urban contractors do not have significant water storage opportunities in their service areas. This provision of the Monterey Amendment allows a contractor to store water in another agency's reservoir or groundwater basin. Examples include water storage programs with Semitropic Water Storage District (a member agency of Kern County Water Agency) involving MWD, Santa Clara Valley Water District and Alameda County Water District. A number of water exchanges are also moving forward following approval of the Monterey Amendment. Dudley Ridge Water District has entered into an exchange agreement with San Gabriel Valley Municipal Water District. Solano County Water Agency is developing an exchange program with Mojave Water Agency whereby Solano provides a portion of its entitlement in wetter years in return for a lesser amount of water in dry years. This firms up the supplies of both agencies. While exchanges cannot be directly attributed to the Amendment, the Amendment facilitates their implementation.

Finally, the Amendment provides a mechanism for using SWP facilities to transport non-Project water for SWP water contractors. (DWR uses other contractual arrangements for wheeling water for the CVP and for other non-SWP water users.) In addition, power for the transport of this non-Project water in SWP facilities will be charged at the same rate as for entitlement water.

Annual Turnback Pool. Prior to the Amendment, water allocated to contractors that was not used during the year would revert to the SWP at the end of the year. No compensation was provided to the contractor for this water, and no other contractors could make use of these supplies during that year. The Turnback Pool is an internal SWP mechanism which provides for pooling potentially unused supplies early in the year for purchase by other SWP contractors at a set price. The Pool was not intended as a water market, but rather as an incentive to return unneeded water early in the year for re-allocation among SWP contractors on a voluntary willing-buyer basis. The Turnback Pool operated successfully on a trial basis during 1996, when more than 200,000 acre-feet were reallocated.

Other Operational Changes. One of the changes brought about by the Amendment is the transfer of DWR's Kern Water Bank property to the agricultural contractors. Participants in the Kern Water Bank include farmers within Kern County Water Agency and Dudley Ridge Water District. It is expected that the Kern Water Bank will be a central water management feature for agriculture in the southern San Joaquin Valley.

Another operational change is that the contractors repaying the costs of constructing the Castaic and Perris terminal reservoirs will be permitted to increase their control and management of a portion of the storage capacity of each reservoir to optimize the operation of both local and SWP facilities. This is expected, for example, to firm up dry year supplies for MWDSC, Castaic Lake Water Agency and Ventura County Flood Control and Water Conservation District.

CVPIA Implementation

USBR and USFWS have been extensively involved in CVPIA implementation since the act's passage in 1992. The act created a number of new federal programs, some of which will take many years to fully implement. Some key areas of CVPIA implementation are summarized below. A more detailed summary of the act is provided in Appendix 2A.

Renewal of CVP Water Service Contracts. CVPIA prohibited execution of new water service contracts (with minor exceptions), except for fish and wildlife purposes, until all of the numerous environmental restoration actions specified in the statute had been completed. The act also provided that existing long-term water service contracts are to be renewed for a 25-year term (as opposed to their previous 40-year term). However, only interim renewals (not more than three years) are allowed until the programmatic EIS required by the act is completed. Beginning October 1997, most existing contracts are subject to a monetary hammer clause to encourage early renewal. Renewed contracts would incorporate new provisions created by CVPIA, such as tiered water pricing.

USBR released its draft PEIS in November 1997. All contract renewals to date have thus been interim renewals. USBR has had over 60 interim contract renewals from the date of enactment through 1996, representing more than 1 maf per year of supply.

Transfers of Project Water. CVPIA authorized transfer of project water outside the CVP service area, subject to numerous specified conditions, including a right of first refusal by existing CVP water users within the service area. Transfers must be consistent with state law, be approved by USBR, and be approved by the contracting water district if the transfer involves more than 20 percent of its long-term contract supply.

USBR has published interim guidelines for administration of this provision, pending formal promulgation of rules and regulations. As of this writing, no off-project transfers have either been approved or implemented under this provision.

Fish and Wildlife Restoration Actions. One of the most controversial elements of CVPIA implementation has been how to manage the 800 taf of CVP yield (see sidebar) dedicated by the act for fishery restoration purposes. This water is available for use on CVP controlled streams (river reaches downstream from the project's major storage facilities on the Sacramento River, American River, and Stanislaus River) and in the Bay-Delta.

CVPIA's Dedicated Water

Section 3406(b)(2) describes the dedicated water as follows:

Upon enactment of this title dedicate and manage annually 800,000 acre-feet of Central Valley Project yield for the primary purpose of implementing the fish, wildlife, and habitat restoration purposes and measures authorized by this title; to assist the State of California in its efforts to protect the waters of the San Francisco Bay-San Joaquin Delta Estuary; and to help meet such obligations as may be legally imposed upon the Central Valley Project under State or Federal law following the date of enactment of this title, including but not limited to additional obligations under the federal Endangered Species Act. For the purpose of this section, the term "Central Valley Project yield" means the delivery capability of the Central Valley Project during the 1928-1934 drought period after fishery, water quality, and other flow and operational requirements imposed by terms and conditions existing in licenses, permits, and other agreement pertaining to the Central Valley Project under applicable State or Federal law existing at the time of enactment of this title have been met.

There has been considerable disagreement over how this water is to be managed and accounted for, in part due to the ambiguity of the statutory language. Use of the dedicated water has also been complicated by its incorporation in the Bay-Delta Accord. Questions have included whether or not the water can be exported from the Delta (especially after the water has been used for instream flow needs in upstream rivers), and if the water may be used for Bay-Delta purposes above Bay-Delta Accord requirements. Initially, USBR and USFWS attempted to develop guidelines or criteria for its management. Subsequent to CALFED's creation, the CALFED Operations Group became one of several forums for attempting to resolve issues about use of the dedicated water. In November 1997, the Department of Interior released its final administrative proposal on management of the dedicated water. The administrative proposal's release was followed by filing of a notice of intent to sue by some of the CVP's agricultural water contractors.

A main purpose of the dedicated water is to meet the act's stated goal of doubling natural production of Central Valley anadromous fish populations (from their average 1967-1991 levels) by year 2002. (Release of water to the San Joaquin River from Friant Dam is excluded from this program.) CVPIA authorizes USBR and USFWS to acquire additional, supplemental water from willing sellers to help achieve the doubling goal. Details of supplemental water acquisition are shown in Chapter 6. The act further allocates additional CVP water supply (in the sense that it reduces the quantity of water which the project could otherwise divert) for instream use in the Trinity River, by requiring that an instream flow of 340 taf per year be maintained through water year 1996 while USFWS finishes a long-term instream flow study.

The act enumerates specific physical restoration measures that the federal government is to complete for fishery and waterfowl habitat restoration. The largest completed measures are a temperature control device at Shasta Dam, at a cost of over $83 million, and a research pumping plant at Red Bluff Diversion Dam. CVPIA allocated part of the costs of some restoration measures to the State of California; the remaining costs are being paid by federal taxpayers and by CVP water and power contractors.

Some of the smaller restoration actions include individual fish-screening projects that USBR and USFWS are cost-sharing with local agencies under the anadromous fish screening program. Examples of these projects are described in Chapter 8.

☞Photo: Shasta Dam TCD

CVPIA required USBR to impose a surcharge on CVP water and power contracts for deposit into a Restoration Fund created by the act. Monies collected into the fund are appropriated by Congress to help fund the many environmental restoration actions required by CVPIA. The act authorizes appropriation of up to $50 million (1992 dollars) per year for the restoration actions. Annual collections into the fund vary with water and power sales. Once appropriated by Congress, the funds can be carried over into subsequent fiscal years. In federal fiscal year 1996, the enacted Restoration Fund budget was $43.5 million, while an additional $38 million was included in the President's FY 1997 budget request to Congress. CVPIA environmental restoration actions can be funded from the general federal treasury, as well as by the Restoration Fund.

☞Photo: duck

CVPIA Waterfowl Habitat Provisions

Most CVPIA environmental restoration measures are focused on fishery needs. However, several provisions specifically address restoring and enhancing waterfowl habitat. The act authorizes a 10-year voluntary incentive program for farmers to flood their fields to create waterfowl habitat, and directs USBR and USFWS to prepare reports on the water supply reliability of private wildlife refuges and on water needs for 120,000 acres of additional wetlands identified in a plan by the Central Valley Habitat Joint Venture (see Chapter 7 for more information). CVPIA's major waterfowl habitat provision is a requirement that, by 2002, USBR and USFWS are to provide specified levels of water supply for the federal, State, and private refuges listed below. Part of this water supply is to come from reallocating of existing CVP supplies, and part from acquisition from willing sellers.

National Wildlife Refuges	*Wildlife Management Areas*	*Resource Conservation District*
Sacramento	Volta	Grasslands
Colusa	Los Banos	
San Luis	North Grasslands	
Merced	Gray Lodge	
Pixley	Mendota	
Delevan		
Sutter		
Kesterson		
Kern		

The act also authorizes DOI to construct or acquire the conveyance facilities or wells needed to supply water to the refuges. USBR has begun an interim water acquisition program for the wetlands supplies, which to date has been focused on year-to-year purchases on the spot market, as described in Chapter 6.

Land Retirement Program. CVPIA authorized the U.S. Department of the Interior to carry out an agricultural land retirement program for lands receiving CVP water. The statute specifies that targeted lands be lands that "are no longer suitable for sustained agricultural production because of permanent damage resulting from severe drainage or agricultural wastewater management problems, groundwater withdrawals, or other causes;" whose retirement would result in improved water conservation in a contracting district; or would help implement recommendations of the San Joaquin Valley Drainage Program's 1990 report. USBR has published interim guidelines for administration of a pilot program, pending formal promulgation of rules and regulations. The federal guidelines were developed in coordination with a state land retirement program established in 1992 under Water Code Section 14902 *et seq*. The State statute limited the retirement program to drainage-impaired lands. The state land retirement program has never been funded, and thus no state acquisitions have been made. As of November 1997, the federal land retirement program had made one purchase--600 acres of drainage-impaired land in Westlands Water District. (This land will be managed for wildlife habitat.) Recently, the federal program solicited proposals from landowners wishing to participate in the retirement program, and received 31 offers to sell lands amounting to 27,500 acres.

CVP Reform Act and CVPIA Administration

In 1995, the CVP Water Association sponsored introduction of HR 1906, the Central Valley Project Reform Act of 1995, a bill which would have made extensive amendments to CVPIA. That bill, which was opposed by the federal administration, did not pass out of the House. CVPIA implementation issues raised by the water users were taken up by the DOI in a 1996 administrative process that has produced a number of concept papers outlining issues with federal implementation of CVPIA.

USBR initially prepared interim guidelines on many provisions of the act, with the intent that the guidelines would remain in place until rules and regulations could be promulgated for those sections of CVPIA involving discretionary actions by the federal government. In some cases, the concept papers produced in the administrative process attempt to clarify or augment the interim guidelines. To date, USBR has not formally promulgated rules and regulations for any CVPIA provision.

Other Administrative Actions and Reports. CVPIA directed the DOI to carry out several other administrative programs and to conduct specified studies. For example, the DOI was directed to conduct a comprehensive assessment and monitoring program for Central Valley fish and wildlife resources, and has been developing a plan to coordinate that program with the real-time Bay Delta monitoring described in the following section. USBR has developed criteria for evaluating the water conservation plans of CVP contractors, as required by the act, and has been reviewing contractors' plans for compliance with the criteria. DWR, DFG, USBR, and USFWS have negotiated a master State-federal cost-sharing agreement for those environmental restoration actions whose costs the act allocated, in part, to California. Funding for the State's share of those costs was provided by voter approval of Proposition 204.

From a water supply standpoint, three CVPIA-mandated reports are of particular interest. In November 1997, USBR released a public review draft of the programmatic EIS required by the act. The PEIS evaluates the impacts of federal implementation of the act, including water supply impacts to the CVP and the impacts of acquiring various levels of supplemental water supply for the anadromous fish restoration program. USFWS has prepared several draft documents relating to estimated Central Valley water needs and water management actions for the AFRP. The most recent draft of the AFRP was published in May 1997. In 1995, USBR released its appraisal-level least-cost CVP yield increase plan, required by the act to identify options for replacing the CVP water supply dedicated for environmental purposes. Although the act directed that the plan be prepared, no statutory authorization was provided for USBR to implement the plan.

FERC Relicensing

The Federal Energy Regulatory Commission, among other things, administers a program of licensing non-federal hydroelectric power plants. FERC licenses contain conditions upon the owners' operation of the plants; typical conditions include instream flow requirements and other fishery protection measures. Licenses for many California hydropower plants will be coming up for renewal in the near future, and FERC has begun to schedule regulatory activities for plants with licenses expiring in 2000 to 2010 (Table 2-7). The relicensing process affords resource agencies and individuals the opportunity to seek higher instream flow requirements, such as those suggested in CVPIA's draft AFRP, when a new license is issued. Use of water for hydropower generation is a nonconsumptive water use. However, changes in the amount and timing of water diverted for power generation can affect other uses downstream. At this time it is not clear what impact deregulation of the electric power industry will have on the plants coming up for relicensing. It appears that current owners of some generating facilities (especially smaller plants) may sell their generation assets as part of deregulation.

Table 2-8. California Hydropower Projects - License Years 2000 - 2010 (projects over 1,000 KW)

License Expiration Date	Project Name	Stream	Licensee	Capacity (KW)
6-14-2000	Lower Tule	Middle Fork Tule River	S. Calif. Edison (SCE)	2,000
9-30-2000	Hat Creek No. 1 & 2	Hat Creek & Pit River	Pacific Gas & Electric (PG&E)	20,000
2-23-2002	El Dorado	South Fork American River	PG&E	20,000
4-26-2003	San Gorgonio No. 1 & 2	San Gorgonio Creek	SCE	2,250
8-31-2003	Vermillion Valley	Mono Creek	SCE	N/A
9-30-2003	Poe	North Fork Feather River	PG&E	142,830
10-31-2003	Pit	Pit River	PG&E	317,000
4-30-2004	Santa Felicia Reservoir	Piru Creek Santa Clara River	United Water Conserv. District	1,434
10-31-2004	U N Fork Feather River	North Fork Feather River	PG&E	342,000
12-31-2004	Donnells & Beardsley	Middle Fork Stanislaus River	Oakdale & South San Joaquin Irrigation Districts	63,990
12-31-2004	Tulloch	Stanislaus River	Oakdale & South San Joaquin Irrigation Districts	17,100
12-31-2004	Stanislaus - Spring Gap	South Fork Stanislaus River	PG&E	175,800
2-28-2005	Borel	Kern River	SCE	9,200
3-31-2005	Portal	Rancheria Creek Big Creek	SCE	10,000
4-30-2005	Kern Canyon	Kern River	PG&E	11,500
2-28-2006	Klamath	Klamath River	Pacificorp	231,000
1-31-2007	Feather River	Off Stream Feather River	DWR	2,165,750
3-27-2007	Kilarc & Cow Creek	Old Cow Creek & Cow Creek	PG&E	8,880
7-31-2007	Upper American River	South Fork American River	Sacramento Municipal Utility District	722,259
7-31-2007	Chili Bar	South Fork American River	PG&E	7,020
11-30-2007	Mammoth Pool	San Joaquin River	SCE	181,000
2-28-2009	Big Creek No. 2A & 8	South Fork San Joaquin River	SCE	480,070
2-28-2009	Big Creek 3	San Joaquin River	SCE	177,450
2-28-2009	Big Creek No. 1 & 2	Big Creek & San Joaquin River	SCE	225,900
3-31-2009	South Fork	Kelly Ridge Canal	Oroville-Wyandotte Irrigation District	104,100
4-30-2009	Santa Ana No. 3	Santa Ana River	SCE	1,500

New ESA Listings

Since Bulletin 160-93, there has been action on federal listing of several fish species having statewide water management significance. In August 1997, the National Marine Fisheries Service listed two coastal steelhead populations as threatened (from the Russian River south to Soquel Creek, and from the Pajaro River south to the Santa Maria River), and one population as endangered (from the Santa Maria River south to Malibu Creek). NMFS deferred listing decisions for six months for other California populations--from the Elk River in Oregon to the Trinity River in California, from Redwood Creek to the Gualala River, and in the Central Valley--due to scientific disagreement about the sufficiency and accuracy of the data available for listing determinations.

Also in 1997, NMFS listed the Southern Oregon/Northern California coast evolutionarily significant unit of coho salmon as threatened. In 1996, NMFS had listed coho salmon in the central coast unit (from Punta Gorda in Humboldt County south to the San Lorenzo River) as threatened.

NMFS has received a petition to list spring-run chinook salmon, and is conducting a review of that species' status. (The spring-run chinook salmon has been listed as a candidate species under the California ESA.) USFWS is currently reviewing the proposed listing of a resident Delta fish species, the Sacramento River splittail. (USFWS had proposed to list splittail in 1994, but a congressional moratorium on listing of new species prevented USFWS from working on the proposal until 1996.)

San Francisco Bay and Sacramento-San Joaquin River Delta

Bay-Delta Accord and CALFED

Representatives from the California Water Policy Council, created to coordinate activities related to the State's long-term water policy, and the Federal Ecosystem Directorate, created to coordinate actions of federal agencies involved in Delta programs, signed a Framework Agreement for the Bay-Delta Estuary in June of 1994. Working together, these agencies have become known as CALFED. The Framework Agreement provides improved coordination and communication between State and federal agencies with resource management responsibilities in the estuary. It covers the water quality standards setting process; coordinates water supply project operations with requirements of water quality standards, endangered species laws, and the

Central Valley Project Improvement Act; and provides cooperation in planning and developing long-term solutions to the problems affecting the estuary's major public values.

In December 1994, State and federal agencies, working with stakeholders, reached agreement on water quality standards and related provisions that would remain in effect for three years. This "Principles for Agreement on Bay-Delta Standards Between the State of California and the Federal Government" (commonly referred to as the Bay-Delta Accord) was based on a proposal developed by urban and agricultural water agencies, and environmental interests. Provisions of the Bay-Delta Accord are intended to (1) establish water quality standards and water project operational constraints; (2) define parameters of ESA implementation and emphasize use of real-time monitoring data in making project operational decisions; and (3) improve conditions in the Bay-Delta Estuary that are not directly related to Delta outflow, such as screening diversions, restoring habitat, or controlling waste discharges. The parties to the agreement made a financial commitment to fund these "non-flow Category III" measures at $60 million per year for the agreement's three-year term. As its expiration in December 1997, the three-year Accord was extended for a fourth year.

To carry out the coordination functions of the Accord, an Operations Group (the "CALFED Ops Group"), composed of representatives from the State and federal water projects and the other CALFED agencies, meets regularly to coordinate project operations. Stakeholders from water agencies, and environmental and fishery groups participate in Ops Group meetings.

Water Quality Standard Setting. SWRCB issued a Draft Water Quality Control Plan for the San Francisco Bay-San Joaquin Delta Estuary in May 1995, incorporating the agreements reached in the Accord. In June 1995, SWRCB approved changes to D-1485 to resolve, on an interim basis, inconsistencies with the Accord and with the SWP's and CVP's voluntary implementation of the standards in the Accord. In 1995, the SWRCB adopted an interim order (WR 95-6) which modified most of the terms and conditions of D-1485 to be consistent with the Bay-Delta Accord. The interim order will expire when a comprehensive water right decision is adopted that allocates final responsibilities for meeting the 1995 Bay-Delta objectives or on December 31, 1998, whichever comes first.

In July 1995, the SWRCB released a Notice of Preparation of an EIR for a water right decision to implement the requirements in the 1995 Bay-Delta Plan, and in December 1995 released a revised NOP describing a preliminary set of alternative approaches to achieve the requirements of the plan. In September 1996, the Board released "Bay-Delta Draft EIR Alternatives Under Consideration," a report summarizing both the alternatives under analysis that may be included in the draft EIR and the assumptions the SWRCB will make to model the alternatives.

The SWRCB intends to issue a water right decision, under CEQA, which will implement the 1995 Bay-Delta Plan by December 1998. SWRCB staff are evaluating seven alternate methods of allocating responsibility to meet flow objectives contained in the 1995 Bay-Delta Plan. These alternatives include:

(1) *SWP and CVP Responsible for Water Right Decision 1485 Flow Objectives*

(2) *SWP and CVP Responsible for 1995 Bay/Delta Water Quality Control Plan Flow Objectives*

(3) *Water Right Priority Alternative* (The Friant Project is assumed to be an inbasin project.)

(4) *Water Right Priority Alternative* (The Friant Project is assumed to be an export project.)

(5) *Watershed Alternative* - Monthly average flow requirements are established for major watersheds based on Delta outflow and Vernalis flow objectives and the watersheds' average unimpaired flow. The parties responsible for providing the required flows are: (1) water users with storage in foothill reservoirs that control downstream flow to the Delta, and (2) water users with upstream reservoirs that have a cumulative capacity of at least 100 taf and who use water primarily for consumptive uses.

(6) *Recirculation Alternative* - The USBR is required to make releases from the Delta-Mendota Canal to meet the Vernalis flow objectives.

(7) *San Joaquin Basin Negotiated Agreement* - The San Joaquin Basin water right holders' responsibility to meet the Bay/Delta Plan objectives is based on an agreement titled "Letter of Intent among Export Interest and San Joaquin River Interests to Resolve San Joaquin River Issues Related to Protection of Bay/Delta Environmental Resources."

Long-Term Solutions - Finding Process for Bay-Delta. The Framework Agreement called for a joint State-federal process to develop long-term solutions to problems in the Bay-Delta estuary related to fish and wildlife, water supply reliability, natural disasters, and water quality. This CALFED Bay-Delta Program is managed by an interagency staff team with the assistance of technical experts from State and federal agencies. It is being carried out under the policy direction of CALFED, with public input being coordinated by the Bay-Delta Advisory Council (BDAC). BDAC is a 31-member advisory panel representing California's agricultural, environmental, urban, business, fishing, and other interests who have a stake in the long term solution of the Bay-Delta Estuary's problems.

The first phase of the CALFED program was to identify problems and goals for the Bay-Delta, and develop a range of alternatives for long-term solutions utilizing an extensive public input process that includes workshops and NEPA/CEQA scoping sessions. This phase concluded with a final report in September 1996 that identified three broad solutions, each of which included a range of water storage options, a system for conveying water, and some programs that are virtually the same in all alternatives. The second phase will conduct a broad-based environmental review of the three alternative solutions and will identify one preferred alternative, and is scheduled to be completed in September 1998. (The draft programmatic EIR/EIS for this phase is scheduled to be released in January 1998.) The final phase involves staged implementation of the preferred alternative, over a time period perhaps as long as 30 years, and will require project-level compliance with NEPA and CEQA.

ESA Administration. The December 1994 Bay-Delta Accord established several principles governing ESA administration in the Bay-Delta during the agreement's term:

- The Accord is intended to improve habitat conditions in the Bay-Delta to avoid the need for additional species listings during the agreement's term. If additional listings do become necessary, the federal government will acquire any additional water supply needed for those species by buying water from willing sellers.
- There is intended to be no additional water cost to the CVP and SWP due to compliance with biological opinion incidental take provisions for presently listed species. The CALFED Operations Group is to develop operational flexibility by adjusting export limits.
- Real-time monitoring is to be used to the extent possible to make decisions regarding operational flexibility. CALFED commits to devote significant resources to implement real-time monitoring.

Suisun Marsh

Decision 1485 ordered USBR and DWR to develop a plan to protect the Suisun Marsh. The Suisun Marsh Preservation and Restoration Act of 1979 authorized the Secretary of the Interior to enter into a Suisun Marsh cooperative agreement with the State of California. This agreement will help mitigate adverse effects of the CVP on fish and wildlife resources of the marsh and to share in the cost of construction, operation, and maintenance activities to protect these resources. The Plan of Protection was subsequently developed by DWR and other interested parties, and initial facilities (water supply distribution systems) were completed in 1981.

In 1986, Congress enacted Public Law 99-546 which authorized the federal government to execute, implement and fund a cooperative agreement among the Suisun Resource Conservation District, DFG, DWR, and USBR that would mitigate the adverse effects of the SWP, CVP, and other upstream diversions on the water quality in the marsh. The agreement, along with a monitoring agreement and a mitigation agreement, was approved in March 1987 and described proposed facilities to be constructed, a construction schedule, cost-sharing responsibilities of the state and federal governments, water quality standards, soil salinity, water quality monitoring, and the purchase of land to mitigate the impacts of the Suisun Marsh facilities themselves. As provided by the agreement, a salinity control structure on Montezuma Slough was completed in 1989. The salinity control gates have effectively reduced salinity in Montezuma Slough and eastern regions of the marsh, and to a lesser degree, in most of the western regions of the marsh.

☞Photo: salinity control gates

Because of the effectiveness of the salinity control gates and increased Delta outflows called for by the State Water Resources Control Board in its 1995 Water Quality Control Plan, the parties to the 1987 Suisun Marsh Preservation Agreement amended the agreement in 1997 to provide for funding of water management activities on the marsh's managed wetlands. Activities such as improving discharge facilities, providing portable pumps with fish screens, employing a water manager, and constructing joint-use water management facilities among landowners will enable landowners to effectively use water from marsh sloughs. The parties decided to maintain the agreement's objectives to improve marsh wildlife habitat, but changed the agreement actions to focus on funding water management activities instead of constructing the large-scale facilities described in the Plan of Protection.

Delta Protection Commission

The Delta Protection Act of 1992 established the Delta Protection Commission to prepare a comprehensive resource management plan for land uses within the Primary Zone of the Delta. On February 23, 1995, the commission adopted the *Land Use and Resource Management Plan for the Primary Zone of the Delta* (Delta Plan). The Commission was created as a regional agency charged with the task of preparing a regional land use and resource management plan and working closely with local governments to ensure that their general plans are brought into conformance with the Commission's plan. Delta counties--including Solano, Yolo, Sacramento, San Joaquin, and Contra Costa--are required to comply with findings of the Delta Plan.

The major goals of the Delta Plan include the following:

- Preserve and protect the natural resources of the Delta, including soils.
- Promote protection of remnants of riparian habitat.
- Promote seasonal flooding and agriculture practices to maximize wildlife use.
- Promote levee maintenance and rehabilitation to preserve the land areas and channel configurations in the Delta;
- Protect the Delta from excessive construction of utilities and other infrastructure, including infrastructure that supports uses and development outside the Delta. Where construction of new infrastructure is appropriate, minimize the impacts of new construction on the integrity of levees, wildlife, and agriculture;
- Protect the unique character and qualities of the Primary Zone by preserving the cultural heritage and strong agricultural base of the Primary Zone. Encourage residential, commercial, and industrial development in existing developed areas.
- Support long-term viability of commercial agriculture and discourage inappropriate development of agricultural lands;
- Protect long-term water quality in the Delta for agriculture, municipal, industrial, water-contact recreation, and fish and wildlife habitat uses, as well as other designated beneficial uses;

- Promote continued recreational use of the land and waters of the Delta; ensure that needed facilities that allow such uses are constructed and maintained; protect landowners from unauthorized recreational uses on private lands; and maximize dwindling public funds for recreation by promoting public-private partnerships and multiple use of Delta lands; and
- Support the improvement and long-term maintenance of Delta levees by coordinating permit reviews and guidelines for levee maintenance; develop a long-term funding program for levee maintenance; protect levees in emergency situations; and give levee rehabilitation and maintenance priority over other uses of levee areas.

As originally authorized, the Delta Protection Commission was to sunset in January 1997. Its sunset date was extended to January 1, 1999. The Commission is participating in the CALFED planning process and in other regional programs such as the San Francisco Estuary Project. The Commission is currently studying existing recreational uses in the Delta in conjunction with the Department of Boating and Waterways and the Department of Parks and Recreation. The Commission continues to monitor proposed land use changes in the Delta.

San Francisco Estuary Project

The San Francisco Estuary Project, established in 1987, is a federal-state partnership established under the authority of the federal Clean Water Act that brought together over 100 government, private, and community interests to develop a plan for protecting and restoring the San Francisco estuary while maintaining its beneficial uses. The Project, jointly sponsored by the EPA and the State of California, is financed by federal appropriations under the CWA and matching funds from state and local agencies.

In 1993, the SFEP's Comprehensive Conservation and Management Plan was completed and signed by the Governor and the EPA. The CCMP contained 145 specific action items to protect and restore the estuary. These action items were classified into the following programs: aquatic resources, wildlife, wetlands management, water use, pollution prevention and reduction, dredging and waterway modification, land use, public involvement and education, and research and monitoring. Since no specific funding existed for implementing these action items, progress has continued under existing federal, state, and local programs. In 1996, the SFEP published a progress report on CCMP implementation which listed ten priorities to be implemented over the next five years. The ten priorities were:

(1) Expand, restore, and protect Bay-Delta wetlands.

(2) Integrate and improve regulatory and scientific monitoring programs.

(3) Create economic incentives that encourage local government to take action to implement measures to protect and enhance the estuary.

(4) Improve the management and control of urban runoff.

(5) Prepare and implement watershed management plans throughout the estuary.

(6) Reduce and control exotic species introductions and spread in the estuary via ship ballast and other means.

(7) Build awareness about CCMP implementation.

(8) Increase public awareness about the estuary's natural resources and the need to protect them.

(9) Implement the Regional Monitoring Program.

(10) Work with CALFED and others (such as CVPIA) to address San Francisco Bay and CCMP considerations in planning efforts and restoration funding decision making.

In July 1997, the Association of Bay Area Governments submitted two CALFED Category III proposals on behalf of SFEP. One proposal was for an educational/outreach program to prevent new introductions of exotic species and the second was for a demonstration project to protect and enhance Delta in-channel islands.

Coordinated Operation Agreement Renegotiation

In 1986, DWR and the USBR signed a Coordinated Operation Agreement obligating the CVP and the SWP to coordinate their operations to meet Decision 1485 standards, in order to address overlapping concerns and interests in the Sacramento-San Joaquin Delta. The agreement authorizes the Secretary of the Department of the Interior to operate the CVP in coordination with the SWP to meet State water quality standards for the San Francisco Bay and the Delta (unless the Secretary determines such operation to be inconsistent with Congressional directives); and provides a formula for sharing the obligation to provide water to meet water quality standards and other in-basin uses. It sets forth the basis for CVP and SWP operation to ensure that each project receives an equitable share of the Central Valley's available water and guarantees that the two systems will operate more efficiently during periods of drought than they would if operated independently. Under the COA, the USBR also agreed to meet its share of future water quality standards established by the SWRCB, unless the Secretary of the Interior determines that the standards are inconsistent with Congressional intent.

Article 14 of the COA provided for periodic review of project operation and the COA, and for future adjustments to the sharing formula should assumed conditions used to calculate the sharing formula change. Since the COA was executed, biological opinions for winter-run chinook salmon and Delta smelt have imposed new operational constraints on both the CVP and the SWP. In addition, the Bay-Delta Accord has established standards the two projects are voluntarily meeting, pending implementation of the standards through the SWRCB water rights proceedings and other processes. As a result of these significant changes, DWR and USBR have begun a review of the sharing formula.

Interstate Issues

California receives most of its water supply from intrastate rivers and groundwater basins. The Colorado River, shared among seven states, is California's largest interstate river. The status of apportionment actions on rivers with long-standing interstate issues is discussed below. Currently, there is no significant activity on interstate groundwater basins. Within the last decade, there had been concerns in California about proposed large-scale groundwater development projects in northern Nevada that could affect interstate basins, but these projects have not been implemented.

☞Photo: Lake Tahoe Dam

Truckee-Carson River System

The Truckee-Carson-Pyramid Lake Water Rights Settlement Act (Title II of Public Law No. 101-618) settles several water rights disputes affecting the waters of Lake Tahoe, the Truckee River, and the Carson River. Among other things, the act makes an interstate apportionment of these waters between the States of California and Nevada. It is the first Congressional apportionment since the Boulder Canyon Project act of 1928. The act addresses several other issues, including settlement of certain water supply disputes between the Pyramid Lake Paiute Tribe of Indians and other users of the Truckee and Carson Rivers. The act also deals with several environmental concerns, including recovery of Pyramid Lake species of fish listed under the federal ESA.

Many of the act's provisions will not enter into effect until several conditions have been satisfied, including dismissal of specified lawsuits (two of which involve California) and negotiation and adoption of a Truckee River Operating Agreement. The act requires that the TROA be negotiated among the DOI, the states of California and Nevada, the Pyramid Lake Paiute Tribe, and the Sierra Pacific Power Company. The TROA addresses implementing the interstate allocation between the two states and implementing an agreement between the Power Company, the Tribe, and the United States which provides for credit storage of water for the listed fish in Pyramid Lake, instream flows, and emergency drought water supplies for the Reno-Sparks area. Negotiation of the TROA has been ongoing since 1991. A draft TROA has been completed and is being analyzed in an EIS/EIR prepared by the DOI. DWR is the lead agency for compliance with the requirements of CEQA. The draft EIS/EIR has been scheduled to be released for public review in 1998.

Walker River

There are currently no significant interstate actions pending on the Walker River as part of the California-Nevada Interstate Compact. A proposed interstate allocation of Walker River waters was negotiated at one time but was not implemented because the Compact was never ratified by Congress, and the Walker River was not included in the settlement legislation for the adjoining Truckee-Carson river basin. In the recent past, interstate activities on the Walker River have involved water quality and fishery issues associated with river operations, rather than interstate water allocation issues.

Klamath River

An interstate compact which provides for the orderly and coordinated interstate administration of the Klamath River was adopted by California and Oregon and ratified by the federal government in 1957. The Compact is administered by a Commission consisting of the Director of the Oregon Water Resources Department and the Director of the California Department of Water Resources. It is chaired by a non-voting federal representative.

For the first 39 years of the Compact, there was little controversy concerning the Upper Klamath River Basin. New issues include recent concerns for endangered species of fish in

Klamath Lake, as well as listed species and candidate species of anadromous fish in the Lower Klamath River; tribal water right claims; preparation of a USBR operating plan for the federal Klamath Project; water shortages during the recent drought; and a comprehensive water rights adjudication in Oregon.

The Klamath River Compact Commission has begun a voluntary consensus process to identify and pursue solutions to water shortages affecting the Upper Klamath River Basin. The effort is focused on getting the parties to agree on ways to secure sufficient water for all needs, rather than asserting claims. The Commission will continue to act as a facilitator as long as there is a possibility of working toward a consensus solution with regard to the waters of the Upper Klamath Basin. The USBR has been cooperating with these efforts.

Colorado River

Colorado River water management activities are described at length in Chapter 9. The major issue facing California is the State's use of Colorado River water in excess of the basic amount allocated to it under the existing body of statutes, court decisions, and agreements controlling the river's water supply among the seven basin states. California's basic apportionment of river water is 4.4 maf of consumptive use per year, as compared to its present consumptive use of about 5.3 maf per year. California's use has historically exceeded its basic apportionment because California has been able to divert and use Arizona's and Nevada's unused apportionments, and to use surplus water. With completion of the Central Arizona Project and the 1996 enactment of a state groundwater banking act, Arizona projects that it will use almost all of its entitlement for the first time in 1998.

California is working with the other basin states to develop a plan to reduce its use to the basic apportionment, as described in Chapter 9.

☞Photo: Hoover Dam

Discussions among the seven basin states and ten Colorado River Indian tribes about changes to Colorado River operating criteria and ways for California to reduce its use of river water began as early as 1991, when the drought in Northern California prompted California to request that USBR declare surplus conditions, so that Southern California could make maximum use of Colorado River water. Discussions about changes to reservoir operations and how surplus and shortage conditions could be established continued, for a time, in a forum known as the

"7/10" (7 states and 10 Indian tribes) process; there has been no recent activity in that forum. Discussions have been underway among the local agencies in California that use Colorado River water to develop a unified position on water allocation and reservoir operations issues.

California has been meeting with the other basin states to outline a plan for California to reduce its use of Colorado River water to the state's basic apportionment. As described in Chapter 9, the plan outline contains actions such as water transfers from agricultural users of river water to urban users in the South Coast region, and lining of, or seepage recovery from, portions of the All-American and Coachella Canals. The urban agencies would provide agricultural water users with funding to implement water conservation measures in exchange for receiving conserved water. As presently envisioned, implementing California's plan could occur in two phases, with projects that are presently well-defined (e.g., canal lining) being implemented in the first phase.

Regional and Local Programs

Local Agency Groundwater Management Programs

In most western states, the use of surface water and groundwater resources is managed by the states. California administers rights to surface water at the state level, but does not administer groundwater resources at a statewide level. Groundwater may be managed under a variety of authorities, ranging from statutory or judicial adjudication of individual basins to several forms of local agency management. Some local agencies have specific statutory authority to manage groundwater resources in their service areas. Other local agencies may manage groundwater under authority provided by general enabling legislation, such as Water Code section 10750 *et seq*. A few counties have also adopted local ordinances dealing with groundwater management.

The 1992 enactment of AB 3030 (section 10750 *et seq*. of the California Water Code) provided broad general authority for local agencies to adopt groundwater management plans pursuant to specified procedures, and to impose assessments to cover the cost of implementing the plans. To date, over 60 local agencies (listed in Table A-1 in Appendix A) have adopted AB 3030 groundwater management plans.

Watershed-Based Planning

There has been increased interest in watershed-based planning within recent years, often prompted by water quality regulatory programs. Watersheds and sub-watersheds are logical units for implementing SDWA source water protection programs and CWA nonpoint source pollution control programs. "Watershed planning" can have a range of meanings -- some people associate watershed planning with small, community-based watershed restoration efforts, often carried out under the aegis of a coordinated resources management plan. Others think of larger-scale efforts that focus on nonpoint source pollution control, such as the SWRCB's watershed management initiative. The largest-scale watershed planning is exemplified by the federal river basin commission efforts attempted in the 1970s, as well as by more recent efforts to integrate river restoration and water management actions within a river basin. The CALFED Bay-Delta program could be considered an example of a large-scale watershed process, one encompassing planning for both water quantity and water quality. Some specific watershed-based planning activities are reviewed below.

Nonpoint Source Pollution Control Watershed Planning. The State Water Resources Control Board and nine Regional Water Quality Control Boards are implementing an integrated watershed management approach to administering water pollution control programs. This approach addresses both point and nonpoint pollution sources, and is based on the premise that water pollution control problems may be best solved at the watershed level, rather than at the level of the waterbody or the individual discharger. The SWRCB's approach includes extensive stakeholder involvement in identifying and prioritizing water quality issues targeted for action on a watershed scale. Each of the regional boards is currently developing a watershed management strategy for its region.

In 1997, the SWRCB, RWQCBs, and EPA undertook a new program known as the watershed management initiative. Through WMI implementation, resources would be focused on targeted watersheds and would be available through a modified administrative process for EPA Clean Water Act grant funding.

To encourage WMI participation, the modified federal grant program will stress new incentives, including seed money, and partnerships with other agencies and local entities. Targeted watersheds and watershed priorities or activities were identified in each of California's nine RWQCB regions. Targeted watersheds and watershed priorities or activities are listed in Table 2-8.

☞Photo: Iron Mountain Mine

One example of a watershed-based water pollution control effort is the Sacramento River Watershed Program which was initiated in 1996 by stakeholders representing federal, State, and local governments; interest groups representing agriculture, mining, and industry; private consulting firms and educational institutions; and private citizens. The program's goal is to ensure that current and potential uses promote the long term social and economic vitality of the region. The SRWP serves as a framework for stakeholders to control the management of their watershed as a whole. It will address all water quality issues the stakeholders believe to be important, beginning with monitoring. Activities in 1996 included organizing the stakeholder group, conducting educational workshops, adopting program goals and objectives, initiating toxicity monitoring in the watershed, and completing a draft comprehensive watershed monitoring plan. Tasks planned for 1997 and 1998 include starting implementation of the comprehensive watershed monitoring plan, identifying impaired waters, identifying priority water quality issues, and formulating water quality management strategies.

Table 2-9. Partial List of Targeted Watersheds and Watershed Activities Identified for the Watershed Management Initiative

Region	Targeted Watershed	Targeted Watershed Priorities/Activities
Region 1 North Coast	Russian/Bodega	Fish restoration, erosion/sedimentation control, riparian enhancement
	Lost River and the Klamath River upstream of Iron Gate Dam	Stream restoration on Clear Lake tributaries (Modoc County)
	Shasta River and tributaries	Irrigation return, nutrient and temperature reductions, and irrigation water conservation
	Scott River and tributaries	Temperature reductions, irrigation water conservation, erosion/sedimentation control
	Other Klamath River tributaries upstream of Scott River confluence	Fish restoration, erosion/sedimentation control
	Garcia Watershed	Fish restoration, erosion/sedimentation control, temperature reductions
	Humboldt Bay	Fish restoration, erosion/sedimentation control
Region 2 San Francisco Bay	Napa River	Riparian and wetland restoration, sediment control, volunteer monitoring
	Petaluma River	Riparian and wetland restoration, sediment control, animal waste control, volunteer monitoring
	Tomales Bay	Riparian restoration, sediment control, mine waste restoration, on-site disposal, volunteer monitoring
	San Francisquito Creek	Riparian and wetland restoration, sediment control, urban runoff prevention and control, volunteer monitoring
	Walnut Creek	Riparian restoration, sediment control, urban runoff prevention and control, volunteer monitoring
	Suisun Marsh	Riparian and wetland restoration, sediment control, construction and agricultural activities, volunteer monitoring and education
	Alameda Creek	Riparian and wetland restoration, sediment control, construction and agricultural activities, groundwater protection, volunteer monitoring and education
Region 3 San Luis Obispo	Salinas River	Agricultural activities, erosion/sedimentation control, riparian and wetland enhancement and restoration
	Morro Bay	Erosion/sedimentation control, abandoned mines, road construction, agricultural activities, riparian and wetland enhancement and restoration
	San Lorenzo	Erosion/sedimentation control, road construction and maintenance, riparian and wetland enhancement and restoration
	Pajaro River	Nonpoint source pollution control, riparian and wetland enhancement and restoration
	Santa Maria River	Nonpoint source pollution control, riparian and wetland enhancement and restoration
Region 4 Los Angeles	Calleguas Creek	Reduce nutrients, pesticides, and sediments in irrigation water; restore aquatic and riparian habitats; flood control; enhance recreational uses
	Ventura River Watershed	Restore aquatic habitats; implement flood control; enhance recreational uses
	Los Angeles River	Restore aquatic and riparian habitats; enhance recreational uses; reduce pollutants, including trash in urban runoff
	Santa Monica Bay	Reduce pollutants from boatyards and marinas; enhance recreational uses; restore wetlands

Table 2-9. Partial List of Targeted Watersheds and Watershed Activities Identified for the Watershed Management Initiative

Region	*Targeted Watershed*	*Targeted Watershed Priorities/Activities*
Region 5 Central Valley	Lower San Joaquin River Watershed	Selenium, agriculture, dairies, temperature, urban runoff
	Sacramento-San Joaquin Delta	Agriculture, sediments, bacteria, dredged material, dissolved oxygen, urban runoff
	Lower Sacramento River Watershed	Agriculture, urban runoff, mercury, heavy metals, nitrates, septic systems, fisheries
	Cache Creek Watershed and Clear Lake	Nutrients (algal blooms), mercury
	Pit River	Hydromodification, nutrients (algal blooms), dissolved oxygen, turbidity/sediments, temperature, agriculture, grazing, silverculture
	Tulare Lake	Salts, pesticides, boron, chloride, molybdenum, sulfate, dissolved oxygen, bacteria, used oil
Region 6 Lahontan	Lower Truckee River	Roadside drainage, erosion control, urban runoff, fisheries habitat improvement, wetlands enhancement, stream restoration
	Upper Truckee River	Sediment control, nutrients from watershed disturbances; watershed education; restoration of wetland function, riparian areas, and/or river morphology and function
	Carson River	Erosion control, disposal of livestock waste, watershed education, wetland/riparian restoration
Region 7 Colorado River	Imperial Valley Watershed	Agricultural pollution control
	Coachella Valley Watershed	Agricultural pollution control, groundwater protection
Region 8 Santa Ana	Chino Basin Watershed	Agricultural runoff, groundwater salt building
	Newport Bay Watershed	Toxics, nutrients, pathogenic organisms, sediments
Region 9 San Diego	San Diego Bay - All Tributaries	Urban runoff, public education
	San Diego Bay	Copper leaching from boat hulls, oil spills
	Otay River Valley	Urban runoff, public education, pollutant loadings
	Sweetwater River	Heavy metals, petroleum products, public education, nutrient transport, sediment transport
	Aliso Creek	Coliform contamination
	Santa Margarita River	Nitrogen and phosphorus loading from agriculture

Upper Sacramento River Fisheries and Riparian Habitat Plan. In 1986, State legislation (SB 1086) was enacted that called for preparation of a management plan to protect, restore, and enhance the fish and riparian habitat and associated wildlife of the Upper Sacramento River. The plan, published in 1989, was prepared by an advisory council working closely with a wide range of agency representatives and stakeholders. The plan recommended implementation of 20 fishery improvement items, several of which (for example, constructing a temperature control device at Shasta Dam and improving fish passage at USBR's Red Bluff Diversion Dam) were subsequently included in CVPIA. Other action items, such as habitat restoration at Mill Creek, are being implemented largely under State authorities and by stakeholder activities.

☞Photo: RBDD Research Pumping Plant

In 1992, the Upper Sacramento River Advisory Council was reconvened by the Secretary for Resources to "complete its earlier work concerning riparian habitat protection and management, including the development of a specific implementation program." The Advisory Council in turn established a Riparian Committee to define the inner and outer zones of a proposed conservation area, provide the basic framework of the riparian plan, and evaluate and recommend a suitable organizational structure to implement the riparian plan. Detailed mapping of the riparian corridor continues, and the committee is refining mechanisms to manage the proposed conservation area.

San Joaquin River Management Program. The San Joaquin River Management Program was initially authorized by 1990 State legislation. This legislation established a SJRMP advisory council and action team, and directed the Secretary for Resources to coordinate their activities in preparation of a management program to develop solutions to water supply, water quality, flood protection, fisheries, wildlife habitat, and recreation needs on a specified segment of the San Joaquin River. Members of the advisory council and action team included State, federal, and local agencies; and stakeholders representing a variety of interests. The members worked together to develop a consensus-based plan addressing the categories of resource issues listed in the authorizing legislation, and the plan was published in 1995. Subsequent State legislation extended the original 1995 sunset date of the program and further directed SJRMP to work with agencies and programs such as CVPIA and CALFED to seek funding for the individual actions recommended in the 1995 plan.

The plan recommended specific projects that could be implemented, as well as further study of other potential projects. Examples of projects in this latter category would be the enlargement of Friant Dam for flood control and other purposes, and the construction of the Montgomery off-stream storage reservoir for fishery water supply. Some of the projects recommended for direct implementation have already been undertaken, including a pilot program for real-time management of agricultural drainage discharge to the San Joaquin River. Prospects appear good for funding other recommended projects through CVPIA's AFRP or the CALFED Category III program.

Conservancies. Other mechanisms for watershed-based planning are conservancies created by special enabling legislation. These conservancies are usually focused on land acquisition or management activities, as typified by the Coastal Commission, or San Francisco Bay Conservation and Development Commission. There are two conservancies, however, with a water-related orientation. The Tahoe Conservancy was created in 1984 to acquire and manage property in the Lake Tahoe Basin for the primary purpose of maintaining the lake's water quality. Other authorized purposes of the conservancy are to provide access to public lands, preserve wildlife habitat, and perform environmental restoration projects. The conservancy is governed by a seven-member board, with members from the city of South Lake Tahoe, El Dorado County, Placer County, the Resources Agency, Department of Finance, and two members appointed by the Legislature. A representative of the U.S. Forest Service is a non-voting board member. Since voter enactment of the 1982 Lake Tahoe Acquisitions Bond Act, the Conservancy has spent about $85 million in land acquisition and erosion control projects in the basin.

The San Joaquin River Conservancy was created by 1992 legislation to acquire and manage lands along the river in Fresno and Madera counties for recreational and wildlife habitat. As established in the enabling legislation, the conservancy is governed by a board of six voting members and seven non-voting ex-officio members.

Non-Governmental Organizations. Some watershed-based planning activities are being carried out by voluntary non-governmental organizations, often in the form of non-profit corporations. These NGOs are typically focused on resource issues in small watersheds, where they may partner with a resource conservation district to carry out specific projects. Examples of such NGOs are found on Mill Creek and Deer Creek in the Sacramento Valley, where local landowners banded together to improve fishery habitat on the creeks. Faced with the potential listing of spring-run chinook salmon under the federal ESA, the landowners decided to implement restoration measures designed to help the fishery recover. Some actions taken or being considered by the NGOs include addressing fish passage problems at water diversion structures, using groundwater for irrigation instead of surface water during times critical to fish passage, and fencing riparian habitat to exclude livestock.

Update on Implementation of Urban Water Conservation MOU

The 1991 *Memorandum of Understanding Regarding Urban Water Conservation in California* defined a set of 16 urban best management practices and procedures for their implementation, and established the California Urban Water Conservation Council composed of MOU signatories (local water agencies, public interest groups, and other interested parties). More than 200 entities have signed the MOU.

The CUWCC has focused its efforts on monitoring the implementation of BMPs and reporting its progress annually to the SWRCB. In the process, the Council developed a plan which provides for an ongoing review process for BMPs and potential BMPs. In late 1996, the Council initiated a systematic review of the BMPs and their definitions. The purpose of this review is to clarify expectations for implementation and to develop a rigorous implementation evaluation methodology. (This review also corresponds with interest in the CALFED Bay-Delta program for developing a water use efficiency common program as part of the Bay-Delta solution.) A list of revised BMPs was adopted in 1997, as described in Chapter 4.

Implementation of Agricultural Efficient Water Management Practices

The Agricultural Efficient Water Management Practices Act of 1990 (AB 3616) required the Department to establish an advisory committee to develop EWMPs for agricultural water use. Negotiations among agricultural water users, environmental interests, and governmental agencies on a memorandum of understanding to implement EWMPs were completed in 1996. The MOU establishes an Agricultural Water Management Council to oversee EWMP implementation, much like the organizational structure that exists for urban BMPs, and also provides a mechanism by which its signatories evaluate and endorse water management plans. By November 1997, the MOU had been signed by more than 29 agricultural water suppliers irrigating about 2.8 million acres of land.

Title Transfer of Reclamation Projects

In the 1990s, there was increasing interest in title transfer of federal water projects constructed under Reclamation law authorities to nonfederal ownership. Generally, these transfer proposals can be divided into three broad categories -- USBR's westside program for small uncomplicated projects, general congressional action dealing with principles for transfer of certain types of projects, and water user-initiated transfers of specific projects. There was additionally a brief period of State-federal negotiations on title transfer of the Central Valley Project. Any transfer of a federal project to nonfederal ownership would require congressional authorization.

In 1995, USBR announced that it was initiating a west-wide program to transfer title of uncomplicated Reclamation projects. Uncomplicated projects were defined as small, single-purpose projects (without hydropower or conservation storage components) which could easily be transferred to project beneficiaries -- typically distribution and conveyance systems. However, transfer of a distribution system would not necessarily "defederalize" a project's service area. For example, a local agency could acquire title to a distribution system but still hold a water service contract with USBR for the water supply made available for diversion. In this instance, the service area would still be held to existing federal requirements such as Reclamation Reform Act acreage limitations and water conservation regulations. USBR has indicated that it will not entertain transfers of several large projects in their entirety under this program, including the CVP. However, the transfer of isolated elements of such projects can be considered under the program. One transfer actively being negotiated under the administrative program is that of the Contra Costa Canal, a facility of the CVP, to Contra Costa Water District. If USBR and CCWD can successfully negotiate terms and conditions for the canal and appurtenant facilities, they would then seek congressional authorization for the transfer. Other California reclamation facilities considered for transfer under the administrative program included two small Sacramento Valley distribution systems associated with the CVP, and the San Diego Aqueduct.

☞Photo: Contra Costa Canal

Legislation was introduced in the 104th Congress that would have directed the DOI to transfer title of reclamation projects whose construction costs have been repaid to the project beneficiaries. This legislation was not enacted. There were several proposals for transfers of individual projects during the 104th Congress, (none located in California) none of which were approved.

In 1992, California and the United States had signed a memorandum of agreement on a process to transfer title of the CVP to the State of California. The federal government subsequently declined to pursue transfer negotiations due to change in the federal administration and the 1992 enactment of CVPIA. In 1995, local agencies that provide operations and maintenance services for much of the CVP system formed a joint powers authority to explore transferring title of the CVP to the local agencies. The CVP Authority proposed to introduce title transfer legislation in the 104th Congress, but legislation was not actually introduced. Solano Project water users also pursued transfer legislation in the 104th Congress. That effort was put on hold while an adjudication of Putah Creek water rights proceeded. At issue were instream flows in the creek. Streamflow in lower Putah Creek is sustained primarily by releases from the Solano Project's Lake Berryessa and by agricultural return flows.

Chapter 3. Water Supplies

This chapter reviews existing water supplies and updates information presented in the 1993 California Water Plan update. Beginning with a brief overview of California's climate and hydrology, this chapter describes how water supplies are calculated and summarized within a water budget framework. A description of California's existing supplies -- surface water, groundwater, and recycled water -- and how these supplies are reallocated through transfers, exchanges, and banking follows. Chapter 3 concludes with a review of water quality considerations that influence how the State's water supplies are used.

Climate and Hydrology

Much of California enjoys a Mediterranean-like climate -- with cool, wet winters and warm, dry summers -- because an atmospheric high pressure belt brings fair weather for most of the year and little precipitation during the summer. During the winter, the storm belt shifts southward, placing the State under the influence of Pacific storms which bring vitally needed rain and snow. Most of California's moisture originates in the Pacific Ocean. As moisture-laden air is transported over mountain barriers, such as the Sierra Nevada, the air is lifted and drops rain or snow on the western slopes. This mountain-induced (orographic) precipitation is very important for the State's water supply.

Average annual statewide precipitation is about 23 inches, corresponding to a volume of 200 maf, over California's land surface. About 65 percent of this precipitation is consumed through evaporation and transpiration by trees, plants, and other vegetation. The remaining 35 percent comprises the State's average annual runoff of about 71 maf. Not all of this runoff can be developed for urban or agricultural use. Much of it maintains healthy ecosystems in California's rivers, estuarine systems, and wetlands. Available surface water supply totals 78 maf when out-of-state supplies from the Colorado and Klamath Rivers are added. Distribution of the State's water supplies varies geographically and seasonally; water supplies also vary climatically through cycles of drought and flood.

Geographic Variability

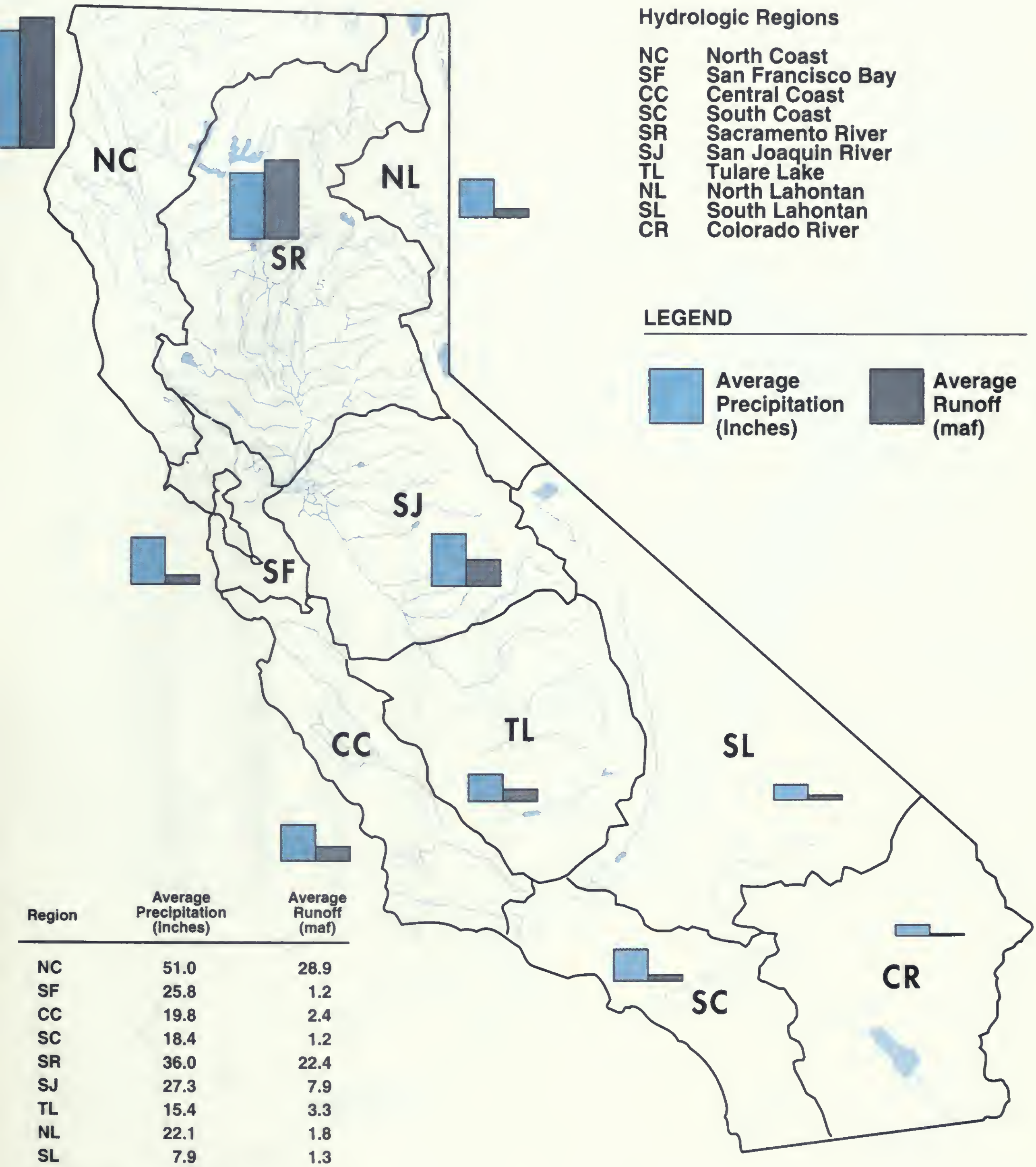
Uneven distribution of water resources is part of the State's geography. More than 70 percent of California's 71 maf average annual runoff occurs in the northern part of the state; the North Coast hydrologic region accounts for 40 percent and the Sacramento River hydrologic region accounts for 32 percent. Figure 3-1 shows average annual rainfall and runoff in California by hydrologic region. About 75 percent of the State's urban and agricultural demands for water is south of Sacramento. The largest urban water use is in the South Coast hydrologic region where roughly half of California's population resides and the largest agricultural water use is in the San Joaquin River and Tulare Lake regions. Fertile soils, a long, dry growing season, and water availability have combined to make the regions among the most agriculturally productive in the world. Flows in wild and scenic rivers in the North Coast Region provide the largest environmental water use. Statewide water use is described in Chapter 4.

In response to the uneven distribution of California's water resources, facilities have been constructed to convey water from one watershed or hydrologic region to another. Figure 3-2 shows larger exports and imports among the State's hydrologic regions.

Seasonal Variability

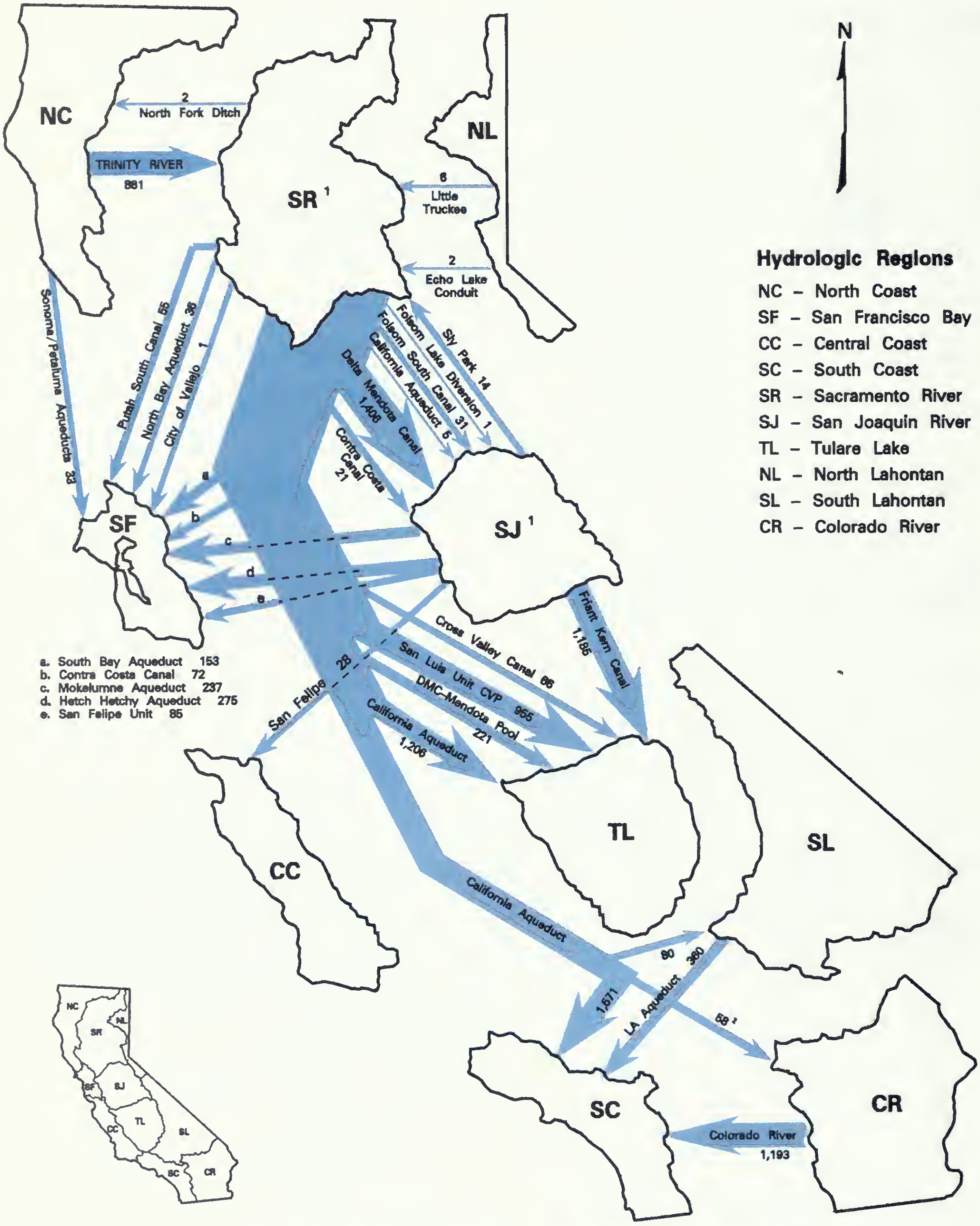
On average, 75 percent of the State's average annual precipitation of 23 inches falls between November and March, with half of it occurring between December and February. A shortfall of a few major storms during the winter causes a dry year; conversely, a few extra storms or an extended stormy period produces a wet year. An unusually persistent Pacific high pressure zone over California during December through February predisposes the year toward a dry year. Figure 3-3 compares average monthly precipitation in the Sacramento River region with precipitation during extremely wet (1982-83) and dry (1923-24) years.

Figure 3-1. Distribution of Average Annual Precipitation and Runoff



Region	Average Precipitation (inches)	Average Runoff (maf)
NC	51.0	28.9
SF	25.8	1.2
CC	19.8	2.4
SC	18.4	1.2
SR	36.0	22.4
SJ	27.3	7.9
TL	15.4	3.3
NL	22.1	1.8
SL	7.9	1.3
CR	5.5	0.2
Entire State	22.9	70.8

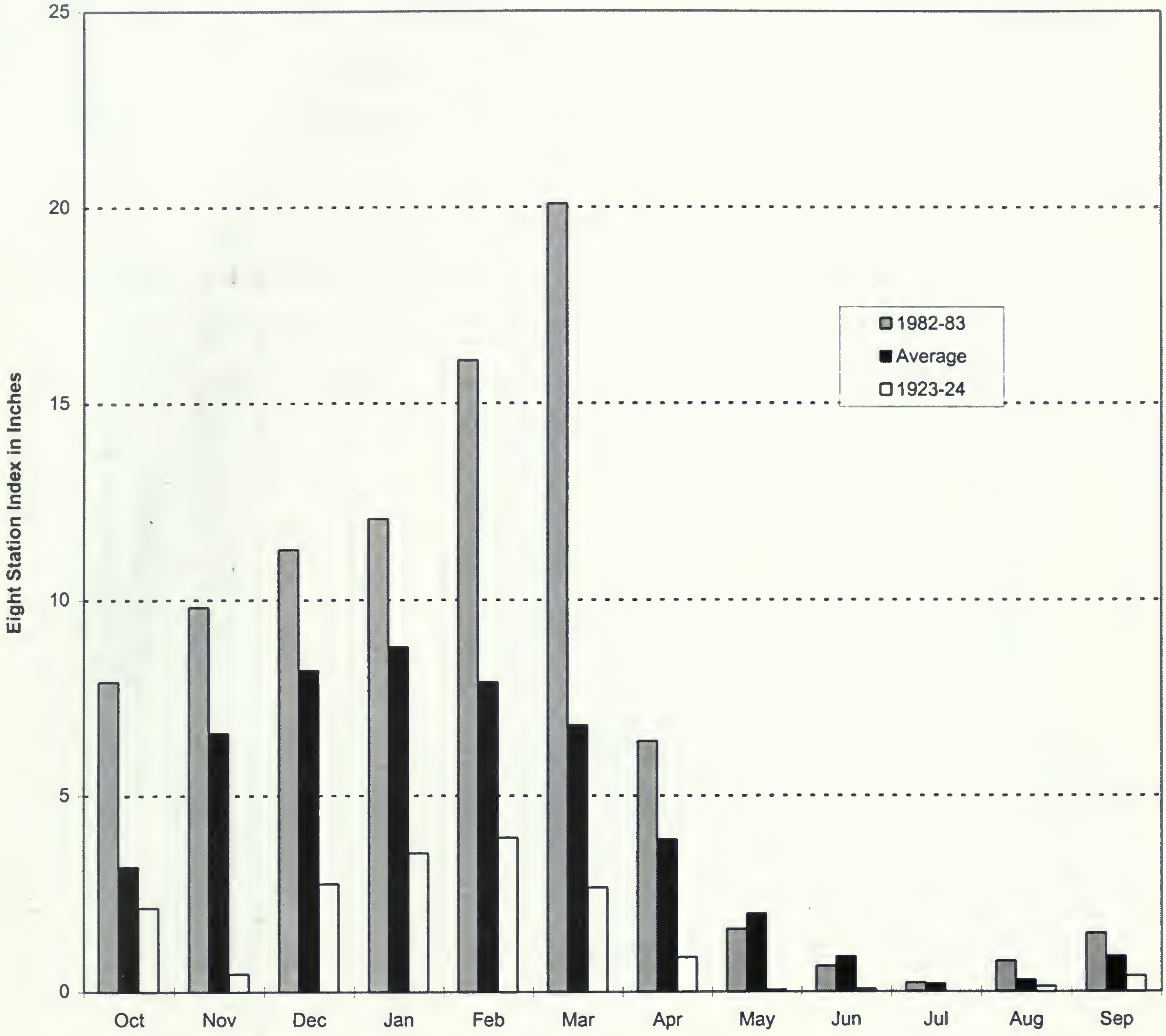
Figure 3-2. Regional Imports and Exports



[1] Exports from the Sacramento-San Jouquin Delta are taken from comingled waters originating in both the Sacramento and San Joaquin River Regions.

[2] Exchange

Figure 3-3. Northern Sierra Eight Station Precipitation Index



Climatic Variability

While average annual runoff volumes are of interest, California's water development has generally been dictated by the extremes of droughts and floods. For example, the average yearly statewide runoff of 71 maf includes the all-time annual low of 15 maf in 1977 and the all-time annual high, exceeding 135 maf, in 1983. Stable and reliable supplies are required to sustain all water uses within the State.

Figures 3-4 and 3-5 show the estimated annual natural runoff from the Sacramento and San Joaquin river basins. Because the Sacramento and San Joaquin river basins provide much of the State's water supply, their hydrologies are often used as indices of water year classification systems. (See sidebar.) Runoff from both basins is subject to substantial climatic variability, such as two 6-year periods of drought in 1929-34 and 1987-92.

Figure 3-4. Sacramento Four Rivers Unimpaired Runoff

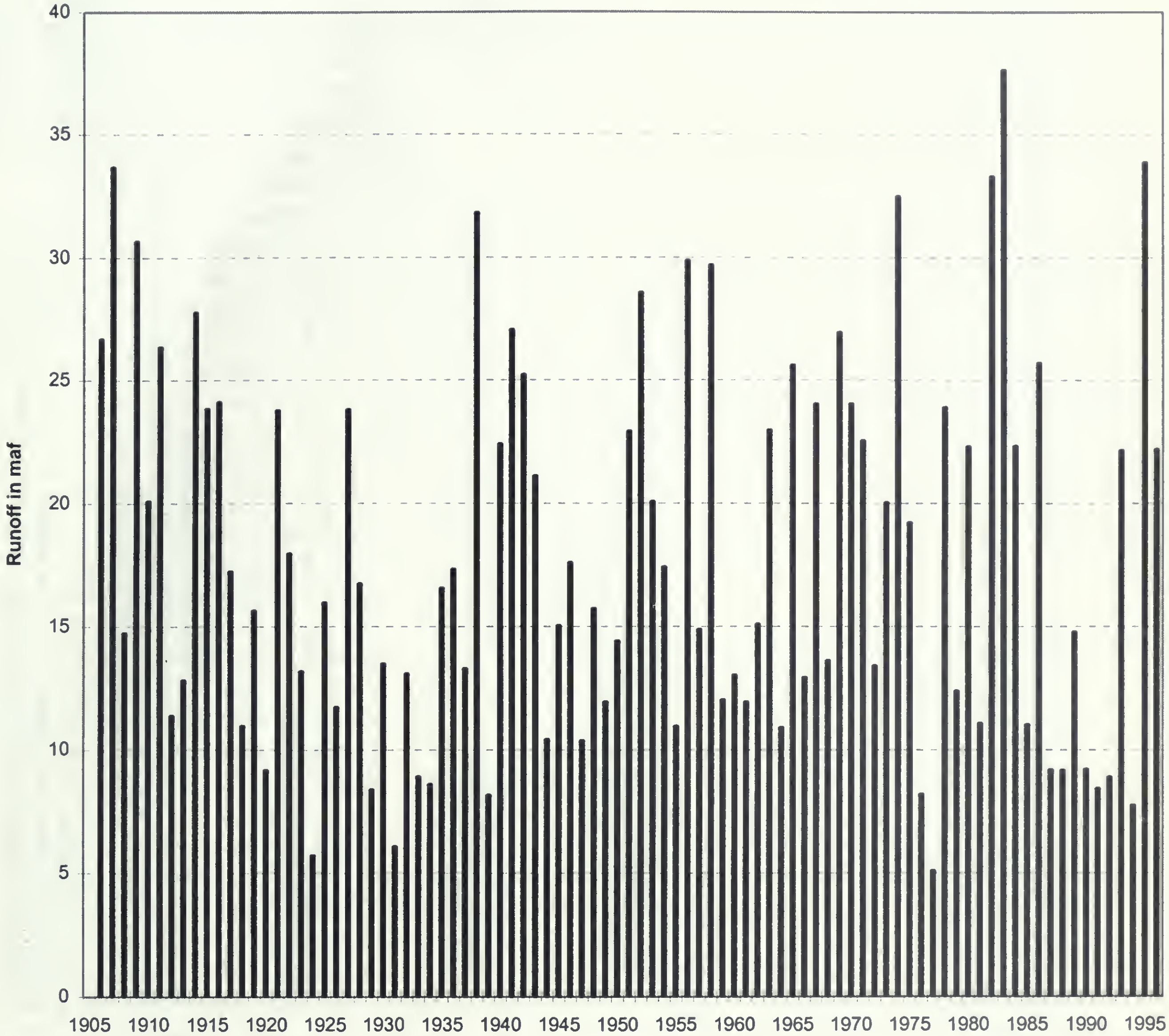
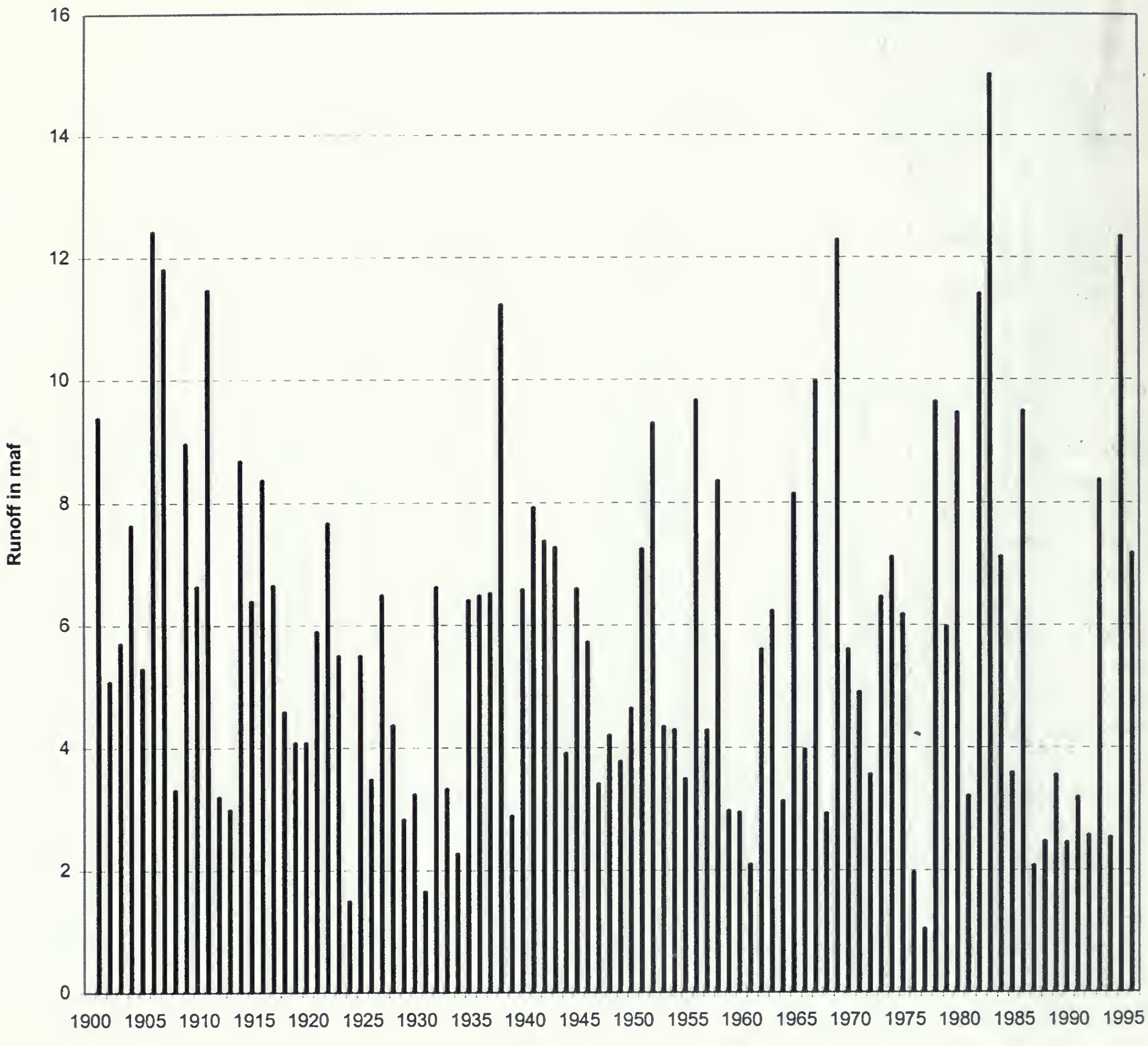


Figure 3-5. San Joaquin Four Rivers Unimpaired Runoff



Water Year Classifications

Water year classification systems provide relative estimates of the amount of water originating in a basin. Because water year classification systems are useful in water planning and regulation, they have been developed for several hydrologic basins throughout California. The Sacramento Valley 40-30-30 Index and the San Joaquin Valley 60-20-20 Index were developed by the SWRCB for the Sacramento and San Joaquin hydrologic basins as part of the Board's Bay-Delta regulatory activities. Both systems include one "wet" classification, two "normal" classifications (above and below normal), and two "dry" classifications (dry and critical), for a total of five water year types.

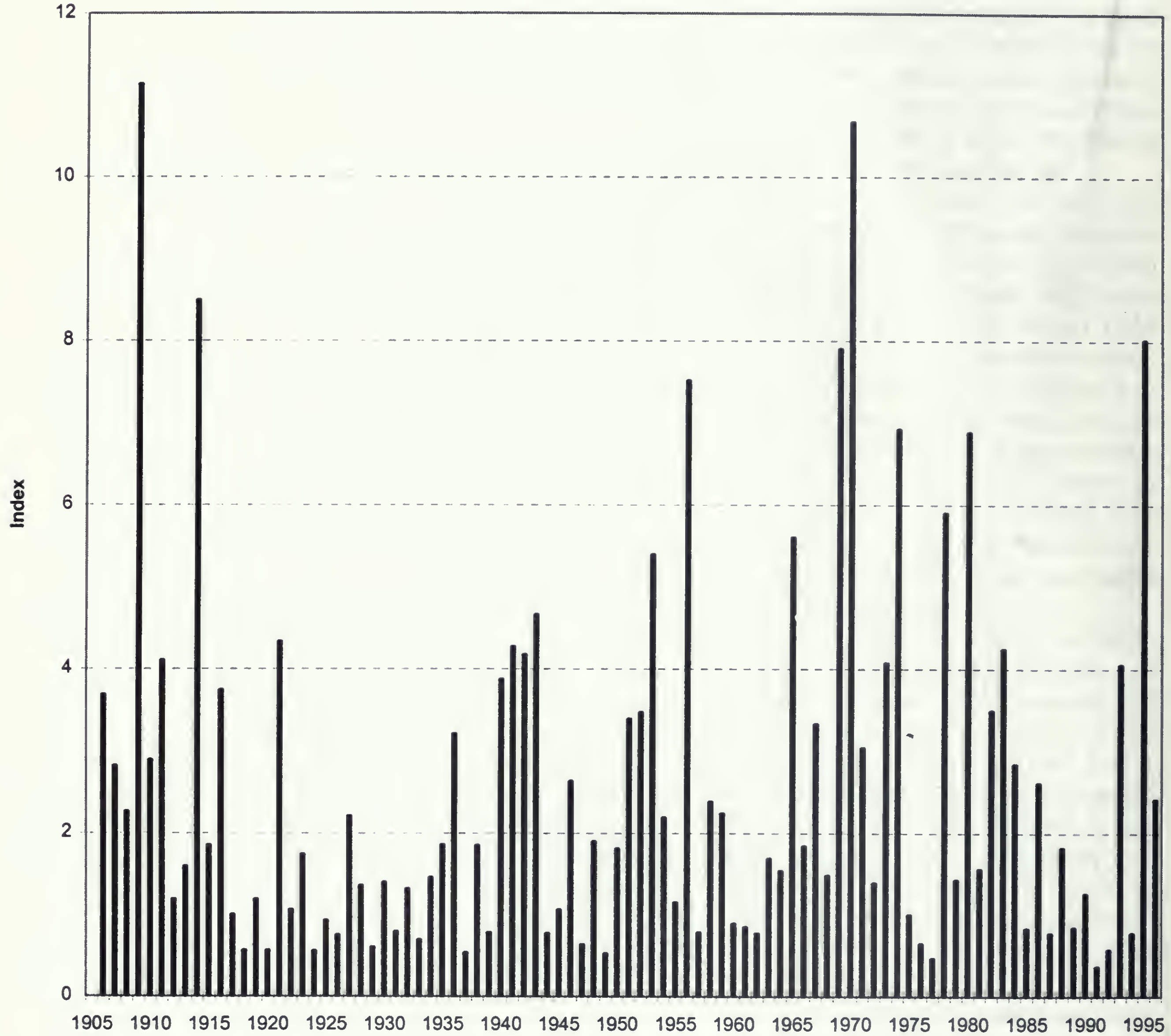
The Sacramento Valley 40-30-30 Index is computed as a weighted average of the current water year's April-July unimpaired runoff forecast (40 percent), the current water year's October-March unimpaired runoff forecast (30 percent), and the previous water year's index (30 percent). A cap of 10 MAF is put on the previous year's index to account for required flood control reservoir releases during wet years. Unimpaired runoff (calculated in the 40-30-30 Index as the sum of Sacramento River flow above Bend Bridge near Red Bluff, Feather River inflow to Oroville, Yuba River flow at Smartville, and American River inflow to Folsom) is the natural stream production unaltered by water diversions, storage, exports, or imports. A water year with a 40-30-30 index equal to or greater than 9.2 maf is classified as "wet." A water year with an index equal to or less than 5.4 maf is classified as "critical." Unimpaired runoff from the Sacramento Valley, often referred to as the Sacramento River Index or the Four River Index, was the dominant water supply index used in the SWRCB's 1978 Delta Plan and in Water Right Decision 1485. The SRI, while still used in the May 1995 Bay-Delta WQCP as a water supply index, is not employed to classify water years. By considering water availability from storage facilities as well as from seasonal runoff, the 40-30-30 Index provides a more representative characterization of water year types than does the SRI.

The San Joaquin Valley 60-20-20 Index is computed as a weighted average of the current water year's April-July unimpaired runoff forecast (60 percent), the current water year's October-March unimpaired runoff forecast (20 percent), and the previous water year's index (20 percent). A cap of 4.5 maf is placed on the previous year's index to account for required flood control reservoir releases during wet years. San Joaquin Valley unimpaired runoff is defined as the sum of inflows to New Melones Reservoir (from the Stanislaus River), Don Pedro Reservoir (from the Tuolumne River), Exchequer Reservoir (from the Merced River), and Millerton Lake (from the San Joaquin River). A water year with a 60-20-20 index equal to or greater than 3.8 maf is classified as "wet." A water year with an index equal to or less than 2.1 maf is classified as "critical."

Although not used to classify water years, the Eight River Index is another important water supply index employed in the May 1995 WQCP. The Eight River Index, defined as the sum of the forecasted unimpaired runoff from the four Sacramento Valley Index rivers and the four San Joaquin Valley Index rivers, is used primarily to define Delta outflow (X2) requirements and export restrictions. Key index months for triggering Delta requirements are December, January, and February. Figure 3-6 shows the Eight River Index computed for January from 1906-1996.

Existing water year classification systems have been useful in planning and managing water supplies; however, they have also shown shortcomings during unusual hydrologic periods. The 1997 water year is one such example. Because of wet antecedent conditions and unusually high precipitation runoff in December and January, the water year was classified as "wet" in spite of a string of dry months that followed this unusually wet period. Water project operators were compelled to meet stringent instream flow and Delta requirements during the subsequent dry months to comply with the "wet" water year classification. Compliance was met through reservoir storage releases, as spring and summer runoff was significantly lower than is in typical wet years. Reservoir levels benefitted only marginally from the wet December and January, as flood control criteria limited the amount of water that could be stored.

Figure 3-6. Eight-River Index Computed for January 1906-96



Droughts of Recent Record. Since the turn of the century there have been numerous multi-year droughts in California, such as 1912-13, 1918-20, 1929-34, 1947-50, 1959-61, 1976-77, and 1987-92. Major reservoirs must be designed to maintain and deliver carryover storage through several years of drought. The seven-year period of 1928-34 established the criteria commonly used to design the storage capacity and water yield of large northern California reservoirs. Many reservoirs built since this drought were sized to maintain a reliable level of deliveries should a repeat of the 1928-34 hydrology occur. Table 3-1 compares the severity of recent droughts with the 1929-34 drought in the Sacramento Valley and San Joaquin Valley. While extended droughts can be costly, a single critical runoff year such as 1977 can also be devastating to a community depending on annual runoff.

Table 3-1. Severity of Extreme Droughts in the Sacramento and San Joaquin Valleys

Drought Period	*Sacramento Valley Runoff*		*San Joaquin Valley Runoff*	
	(maf/yr)	*(% Average 1906-96)*	*(maf/yr)*	*(% Average 1901-96)*
1929-34	9.8	55	3.3	57
1976-77	6.6	37	1.5	26
1987-92	10.0	56	2.8	47

Groundwater generally supplies about 30 percent of California's urban and agricultural applied water use. In drought years, when surface water supplies are reduced, groundwater can provide an even larger percentage of use. As a result of increased groundwater pumping during droughts, groundwater levels may decline significantly in many areas. For example, during the first five years of the 1987-92 drought, groundwater extractions exceeded groundwater recharge by 11 maf in the San Joaquin Valley.

Floods of Recent Record. Climatic variability results in floods as well as droughts. Wet water years are not necessarily indicative of flood conditions. Water year 1983 was the wettest in California this century. However, major flooding did not occur during this period. Floods may occur as the result of: (1) an extended period (usually in the winter) of high precipitation and runoff over a large area, (2) spring and early summer snowmelt floods, unique to high elevation central and southern Sierra Nevada basins, and (3) local area thunderstorms originating from moist tropical or subtropical air. Local area thunderstorms, sometimes caused by remnants of eastern Pacific hurricanes crossing the State, produce flash floods in the desert regions and in other areas of southern California.

The most damaging flooding comes from extended-period regional winter storms which can sweep across all of northern California. These storms are slow moving, with a long southwesterly fetch extending toward Hawaii. The frontal zone can ripple back and forth several hundred miles, producing almost continuous rain up to fairly high elevations in northern or central California (less commonly in southern California).

Several major flood events have occurred in California since the disastrous floods of the 1950s, which were an impetus for development of several major flood protection facilities. In January 1997, California was confronted with the largest and most extensive flood disaster in its history. Rivers across the State from the Oregon border to the southern Sierra reached flood stages. Flood volumes of some rivers exceeded channel capacities by as much as seven times. In many major river systems, flood control dams reduced peak flows by half or more. However, in some areas, leveed flood control systems were overwhelmed, and flood damage costs in those areas plus the costs to replace, restore, and rehabilitate facilities are nearing $2 billion. These floods not only tested the Sacramento-San Joaquin flood control system, but left many of the State's citizens apprehensive about how much protection they can expect from the current leveed flood control system. Table 3-2 shows estimated unregulated runoff from a few of the State's larger floods since the 1950s.

Table 3-2. Major Floods Since the 1950s

River	Location	Date	Unregulated Runoff Estimates	
			Max 1-Day (cfs)	Ave 3-day (taf)
Sacramento	Shasta Dam	Jan-74	196,000	779
		Feb-86	126,000	681
		Jan-97	216,000	1,000
Feather	Oroville Dam	Dec-64	179,000	984
		Feb-86	217,000	1,113
		Jan-97	298,000	1,392
Yuba	New Bullards Bar Dam	Dec-64	64,000	306
		Feb-86	69,000	327
		Jan-97	88,000	398
American	Folsom Dam	Dec-64	183,000	835
		Feb-86	171,000	988
		Jan-97	249,000	977
Mokelumne	Camanche Dam	Dec-64	36,000	171
		Feb-86	28,000	149
		Jan-97	76,000	233
Stanislaus	New Melones Dam	Dec-64	44,000	198
		Feb-86	40,000	246
		Jan-97	73,000	298
Tuolumne	New Don Pedro Dam	Dec-64	72,000	306
		Feb-86	53,000	294
		Jan-97	120,000	548
Merced	New Exchequer Dam	Dec-64	33,000	136
		Feb-86	30,000	164
		Jan-97	67,000	262
San Joaquin	Friant Dam	Mar-95	39,000	156
		Feb-86	33,000	176
		Jan-97	77,000	313
Truckee	Reno	Oct-63	25,000	79
		Feb-86	22,000	112
		Jan-97	37,000	148
Cosumnes	Michigan Bar	Dec-64	29,000	115
		Feb-86	34,000	196
		Jan-97	60,000	N/A
Eel	Scotia	Dec-64	648,000	2,936
		Feb-86	304,000	1,515
Santa Ynez	Lompoc[1]	Jan-69	38,000	175
Salinas	Spreckles[1]	Feb-69	70,000	90
		Mar-86	13,300	66
		Feb-80	36,200	100
Santa Clara	Saticoy	Feb-69	92,000	270

[1] Regulated flows

Water Supply Calculation

This update of the California Water Plan calculates existing water supply and demand, then balances forecasted future demand against existing supply and future water management options. The balance, or water budget, is shown on a regional basis in Chapters 7-9 and on a statewide basis in Chapter 10. The following section describes the method for calculating water supplies within a water budget framework. Two water supply scenarios, an average year and a drought year, are presented to illustrate overall supply reliability.

Water Budgets

Water supplies are classified into three groups to develop Bulletin 160 water budgets: surface water, groundwater, and recycled/desalted water. Table 3-3 shows California's estimated water supply for 1995 and 2020 levels of development with existing facilities and programs. Facility operations are assumed to be in accordance with the State Water Resources Control Board's Order WR95-6 for Delta supplies.

Table 3-3. California Water Supplies with Existing Facilities and Programs[1] (taf per year)

Supply	*1995 Average*	*Drought*	*2020 Average*	*Drought*
Surface				
CVP	7,004	4,821	7,347	4,889
SWP	3,126	2,000	3,439	2,115
Other Federal Projects	910	694	912	683
Colorado River	5,176	5,227	4,400	4,400
Local	11,054	8,484	11,073	8,703
Req. Environmental Flow	30,532	16,200	30,532	16,200
Incidental Reuse	6,441	5,596	6,876	6,039
Groundwater[2]	12,493	15,784	12,591	15,906
Recycled & Desalted	324	333	469	470
TOTALS (rounded)	**77,060**	**59,138**	**77,638**	**59,403**

[1] Bulletin 160-98 presents water supply data as applied water, rather than net water. This distinction is explained in the following section. Past editions of Bulletin 160 presented water supply data in terms of net supplies.

[2] Excludes groundwater overdraft

Surface water sources include developed supplies from the Central Valley Project, the State Water Project, the Colorado River, other federal projects, and local projects. (As described in the sidebar, operations studies are used to evaluate the delivery capabilities of the CVP and SWP.) Surface water also includes the supplies for required environmental flows. Required environmental flows include undeveloped supplies used for designated wild and scenic rivers, as well as developed supplies used for instream flow requirements and Bay-Delta salinity and outflow requirements. Finally, surface water includes supplies available for incidental reuse. Urban wastewater discharges and agricultural return flows, if available and of acceptable quality to downstream users, are examples of incidental reuse water.

Groundwater includes developed subsurface water and incidental water reuse through deep percolation. Groundwater excludes long-term basin extractions in excess of long-term basin inflows. This long-term annual average difference between extraction and recharge, defined in Bulletin 160 as overdraft, is treated as a shortage in water budget calculations.

Water supplies from recycling and desalting do not include all water that is reclaimed and reused through treatment technologies. The Bulletin 160-98 recycled/desalted category includes only the new supplies that, if not recycled, would have discharged from a wastewater treatment plant to the ocean or to a salt sink. Treated water that would otherwise be available for incidental reuse, at a quality acceptable for beneficial use downstream, is not considered a new supply.

The State's 1995 level annual average year supply is about 77.1 maf, including about 30.5 maf of dedicated flows for environmental uses. Even with a reduction in Colorado River supplies to California's 4.4 maf basic apportionment, average annual statewide supply is projected to increase 0.58 maf by 2020 without additional water supply options. While the projected increase in water supply is due mainly to higher CVP and SWP deliveries (in response to higher 2020 level demands), new water production will also result from groundwater and recycling facilities currently under construction.

The State's 1995 level annual drought year supply is about 59.1 maf, of which about 16.2 maf is dedicated for environmental uses. Annual drought year supply is projected to increase 0.27 maf by 2020 without additional water supply options. The projected increase could come from higher CVP and SWP deliveries and new production from surface, groundwater, and recycling facilities currently under construction.

Operations Studies

Computer simulations, also known as operations studies, are performed to estimate the delivery capabilities of the CVP and SWP under average year and drought year conditions. Two widely used computer models for conducting CVP/SWP operations studies are the Department's DWRSIM and USBR's PROSIM. Most Bulletin 160-98 studies were performed with DWRSIM.

DWRSIM is designed to simulate the monthly operation of the CVP and SWP system of reservoirs and conveyance facilities under different hydrologic sequences. These hydrologic sequences are typically based on a 73-year record of historic hydrology from 1922 through 1994. DWRSIM simulates the availability, storage, release, use, and export of water in the Sacramento and San Joaquin River systems, the Delta, and the aqueduct and reservoir systems south of the Delta. The model provides numerical output on parameters such as reservoir storage, releases, Delta inflows, exports, and outflows. The model operates the CVP and SWP system to provide the maximum water withdrawal from the Delta allowed by regulatory constraints, up to the total water demand. Additional system operational objectives (e.g., reservoir carryover storage), physical constraints (e.g., reservoir and pumping plant capacities), and institutional agreements (e.g., Coordinated Operations Agreement) also affect the simulated operation.

In considering the results of a project operations study, it is important to note that conditions in a specific model year do not match those observed in the actual year. Simulated hydrology deviates from historic hydrology because the 73-year sequence is normalized to reflect existing or forecasted future land development and consumptive use conditions. Project deliveries and reservoir operations deviate from historic conditions because they are optimized for a specific level of demand over the entire hydrologic sequence. The results should be interpreted as average project delivery capability over a 73-year sequence of hydrology rather than in water years 1922 through 1994. Project deliveries over this long sequence of hydrology provide an indication of the system's average performance, as well as the performance over a wide range of wet and dry years.

An example of the use of operations studies is provided later in this chapter when we describe how operations studies were used to evaluate CVP/SWP delivery impacts associated with the SWRCB's Order WR 95-6 Delta standards.

Bulletin 160-98 water budgets are computed using applied water data. Applied water refers to the amount of water from any source employed to meet the demand of the user. It is the quantity of water delivered to the intake of a city water system or factory, a farm headgate or similar measuring point, a marsh or wetland either directly or indirectly by incidental drainage flows, or the portion of stream flow dedicated or reserved to instream uses.

Previous Bulletin 160 updates used net water data in their water budgets. Bulletin 160-98 switched from a net water methodology to an applied water methodology in response to public comments on Bulletin 160-93. Because applied water data are analogous to agency water delivery data, water budgets based on an applied water methodology are easier for local water agencies to review. Applied water supply values are greater than net water supply values because they include incidental reuse of surface and groundwater supplies.

A second water budget modification adopted for Bulletin 160-98 was the elimination of groundwater overdraft as a base year supply component. While groundwater overdraft does provide a temporary water supply, the practice does not provide a sustainable water supply over the long term. Bulletin 160-98 now counts base year demand that is met by groundwater overdraft as a shortage and not as a supply. And as in previous updates, Bulletin 160-98 does not show groundwater overdraft as a future year supply.

Water Supply Scenarios

As discussed at the beginning of Chapter 3, California is subject to a wide range of hydrologic conditions and, therefore, experiences annual variability in its water supplies. Knowledge of water supplies under a range of hydrologic conditions is necessary to evaluate the needs that water managers must meet. Two water supply scenarios -- average year conditions and drought year conditions -- were selected from among a spectrum of possible water supply conditions to represent variability in the regional and statewide water budgets.

Average Year Scenario. The average year supply scenario represents the average annual supply of a system over a long planning horizon. Historic data from water supply projects are normalized to represent average water year conditions. Average year supplies from the CVP and SWP are defined by operations studies as the average annual delivery capability of each project over a 73-year hydrologic sequence. For required environmental flow, average year supply is estimated differently for each of its components. Wild and scenic river flow is represented by the long-term average natural flow. Instream flow requirements are defined for an average year under specific agreements, water rights, court decisions, and congressional directives. Bay-Delta outflow requirements are estimated from operations studies.

Drought Year Scenario. For many local water agencies, and especially urban agencies, drought water year supply is the critical factor in planning for water supply reliability. Traditional drought planning often uses a design drought hydrology to characterize project operations under future conditions. For a planning region with the size and hydrologic complexity of California, selection of an appropriate statewide design drought is not a trivial task. Based on several criteria, water years 1990 and 1991 were selected to represent the drought year scenario for Bulletin 160-98. (The 1990-91 drought was also used to represent drought year conditions in Bulletin 160-93.) This period was selected for the regional and statewide water budgets because it was a recent statewide event and water demand and supply data were readily available. The 1990-91 drought year scenario has a recurrence interval of about 20 years, a 5 percent probability of occurring in any given year. This is typical of the level of drought used by many local agencies for routine water supply planning. For extreme events such as 1976 and 1977, many agencies would implement shortage contingency measures such as mandatory rationing.

The statewide occurrence of dry conditions during 1990-91 was another consideration in selecting it as a representative drought. Because of the size of California, droughts may or may not occur simultaneously throughout the entire state. For example, the most significant prolonged drought on the Sacramento and Feather Rivers in northern California occurred in 1929-34. But on the Santa Ynez River in southern California, the driest prolonged period was from 1946 to 1951. See Figure 3-7.

Defining a representative drought in southern California is complicated by the region's access to imported supplies from the Colorado River. The Colorado River watershed is large (about 244,000 square miles) and experiences hydrologic conditions different than California's. As a result, southern California's water supply is less affected by severe drought in northern California. Figure 3-8 presents Colorado River flow at the Lee Ferry stream gage to illustrate historic river basin hydrology.

Figure 3-7. Sacramento River and Santa Ynez River Runoff

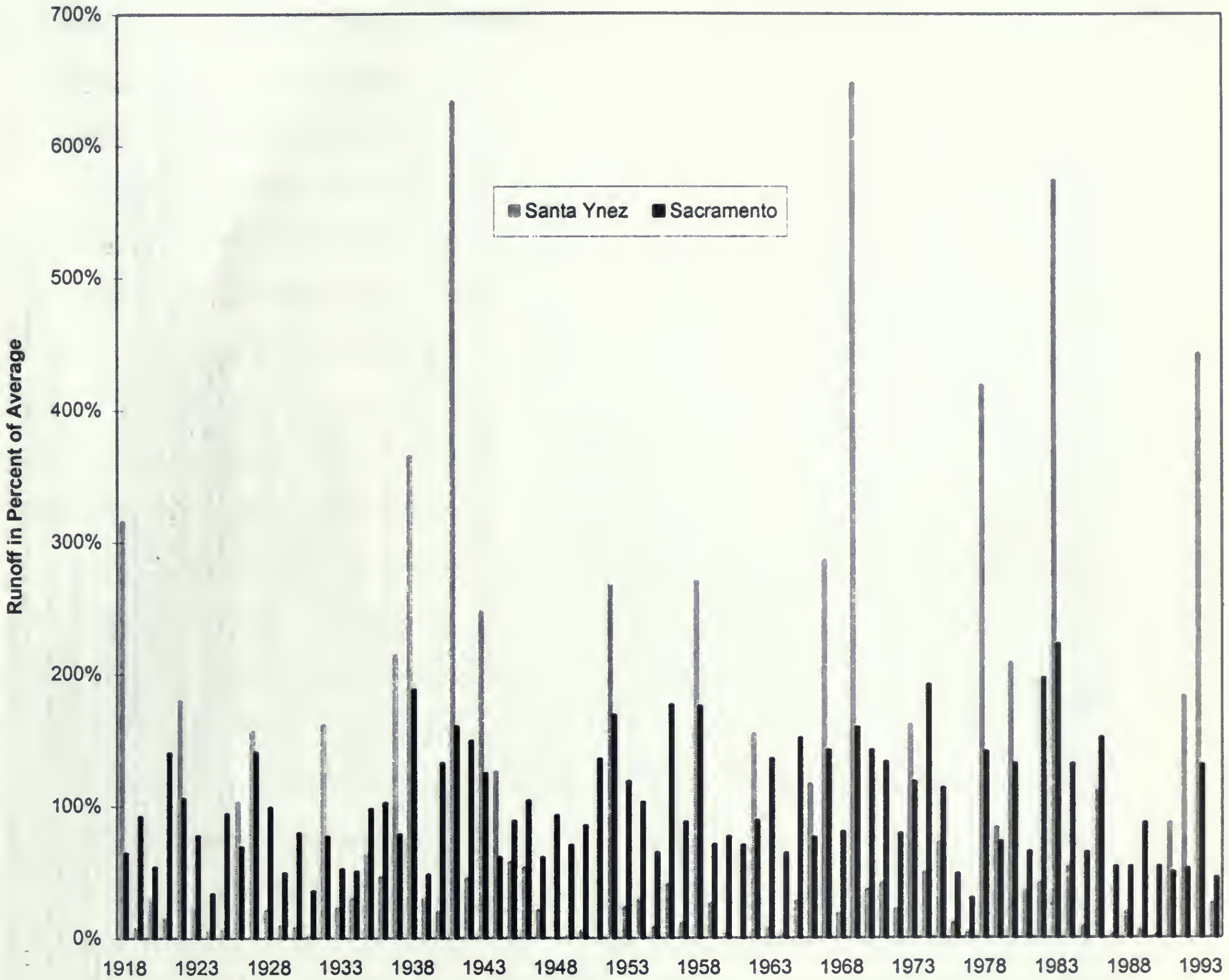
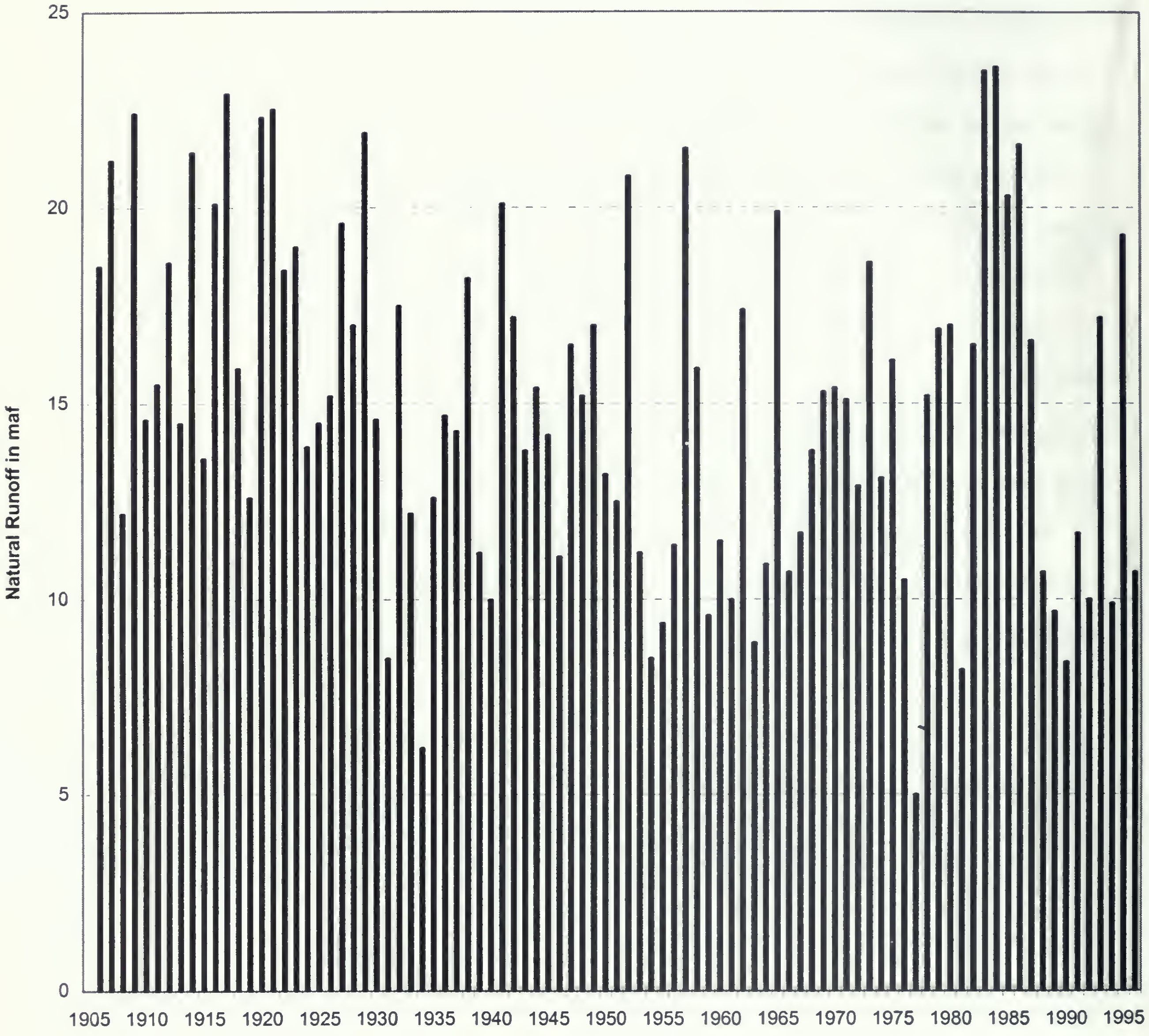


Figure 3-8. Colorado River Unimpaired Runoff at Lee Ferry



Other Drought-Related Considerations. During low runoff years, carryover storage in surface water reservoirs is an important source of water supply. At the beginning of an extended dry period, the drought's duration is unknown. Therefore, to manage deficiencies, water may be released from storage according to some risk analysis procedure. As the drought continues, the procedure may impose progressively larger deficiencies.

Carryover storage was used to supplement water deliveries during the low runoff years of 1987-92, thereby minimizing the initial impacts of the drought on many water users. Figure 3-9 shows SWP and CVP deliveries during this period. Although the drought lasted six years, deficiencies were not imposed on deliveries by either project during the first three years of the drought. During the final three years both projects imposed significant deficiencies. Figures 3-10 through 3-13 show how Shasta, Oroville, New Melones, and Cachuma reservoirs were operated during the 1987-92 drought.

Surface water supplies were developed in California to balance the uneven distribution of water supply and water demand. The following section describes the State's major surface water development projects. (In response to public comments on Bulletin 160-93, we have expanded the description of surface water projects to provide more detail on the larger local agency projects.) A discussion on reservoir and river operations follows. The section concludes by addressing surface water supply impacts associated with recent events and reservoir reoperation.

Figure 3-9. CVP and SWP Deliveries During 1987- 92 Drought

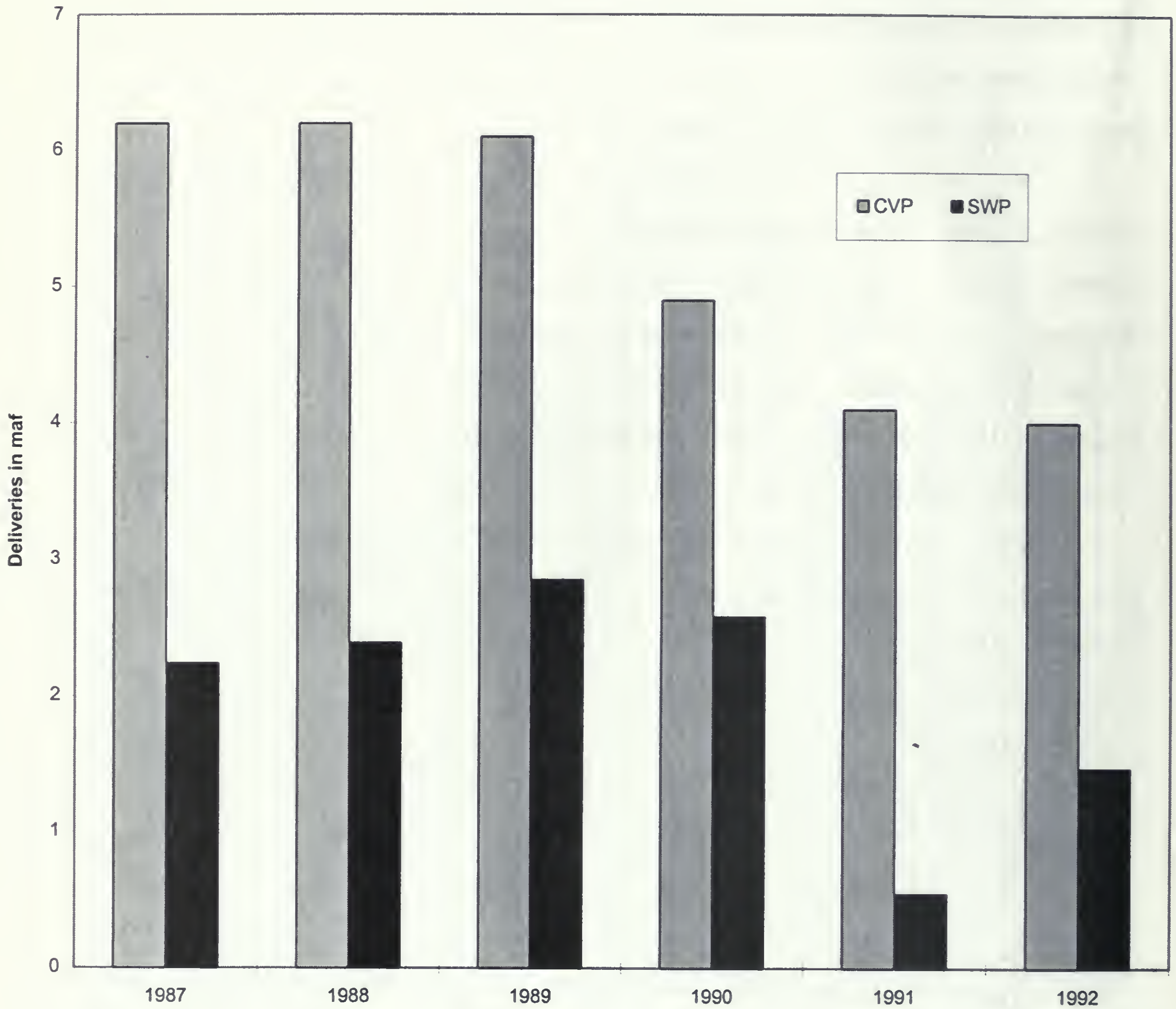


Figure 3-10. Maximum/Minimum Storage During 1987-92 Drought: Shasta

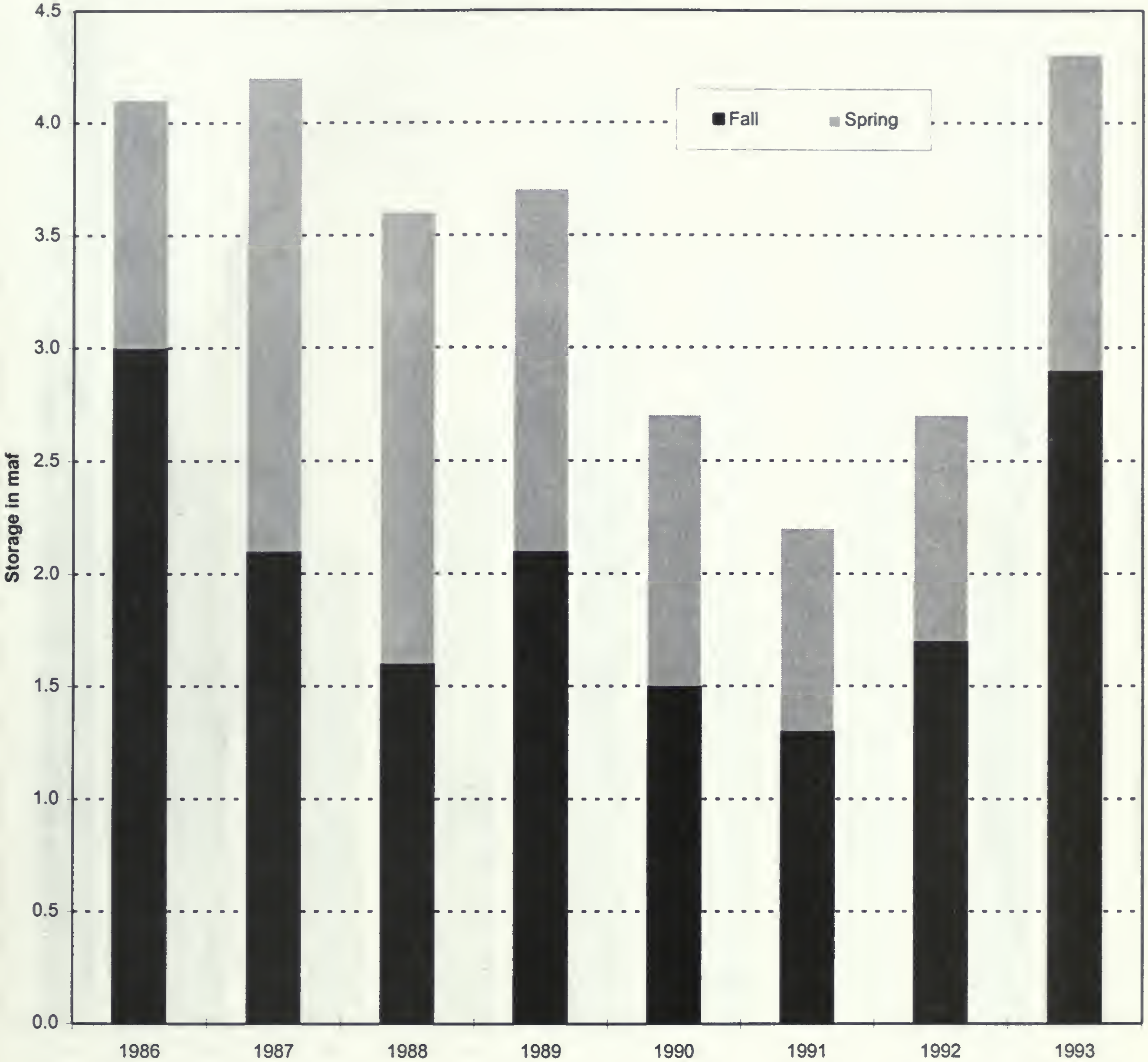


Figure 3-11. Maximum/Minimum Storage During 1987-92 Drought: Oroville

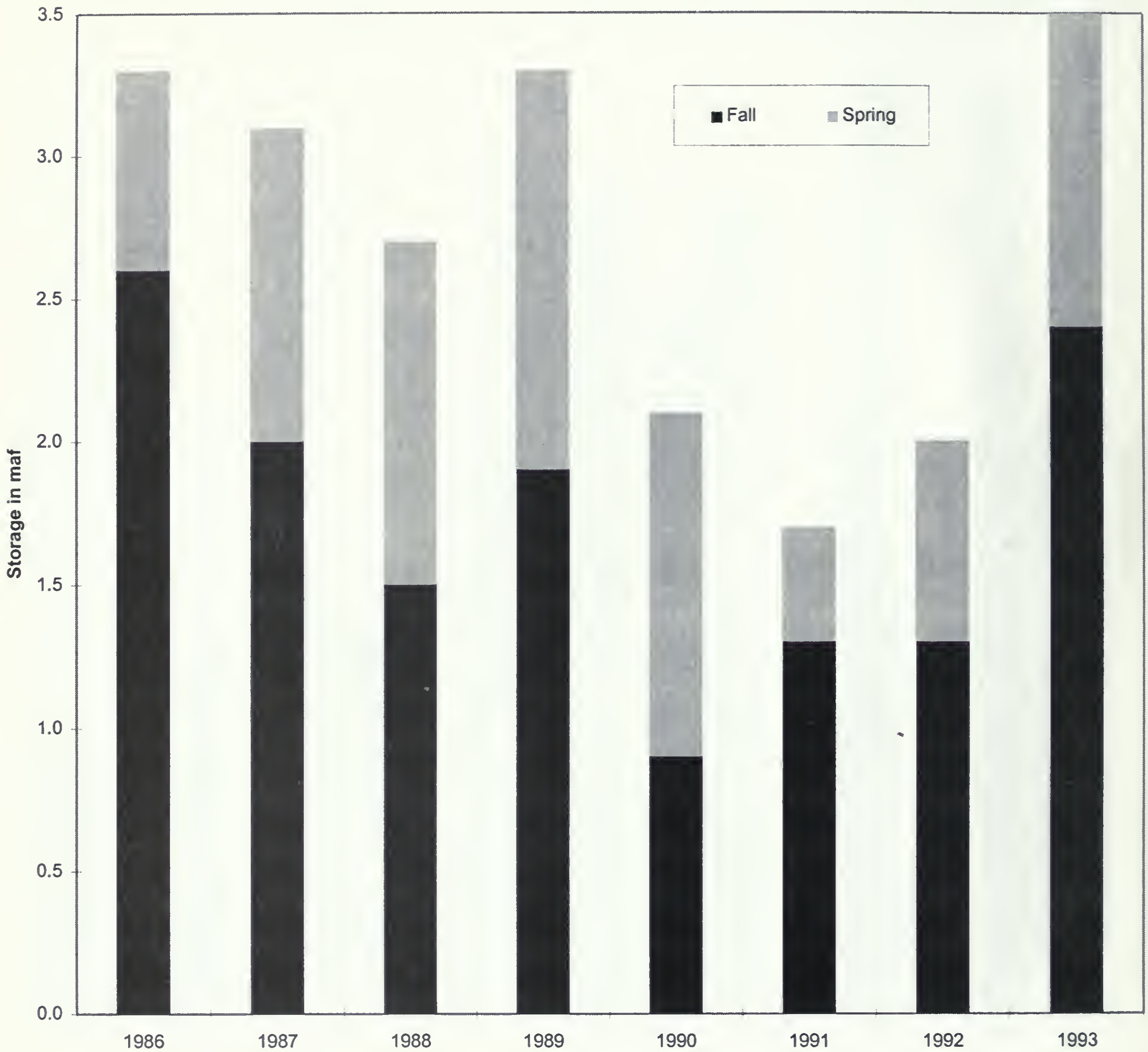


Figure 3-12. Maximum/Minimum Storage During 1987-92 Drought: New Melones

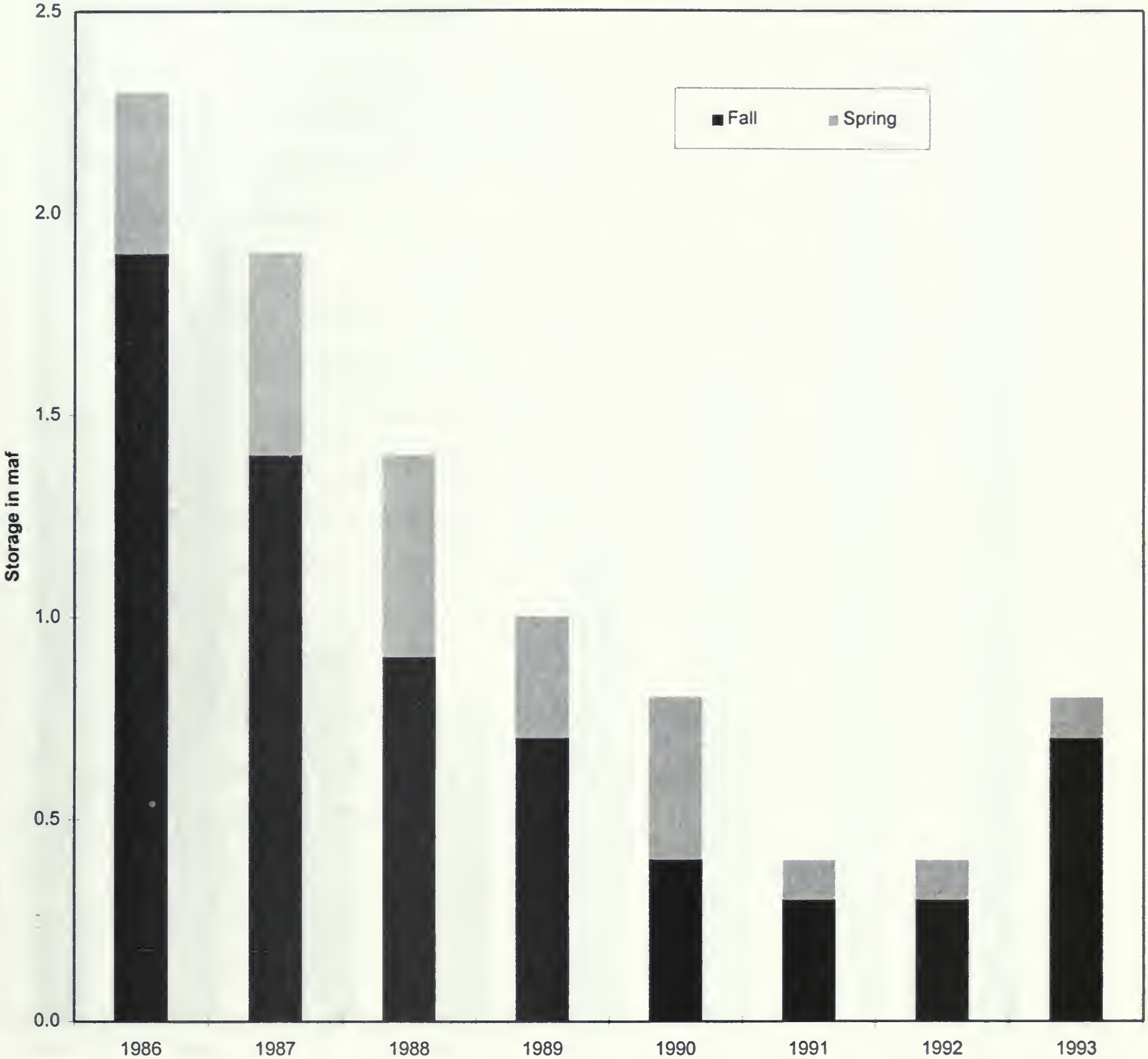
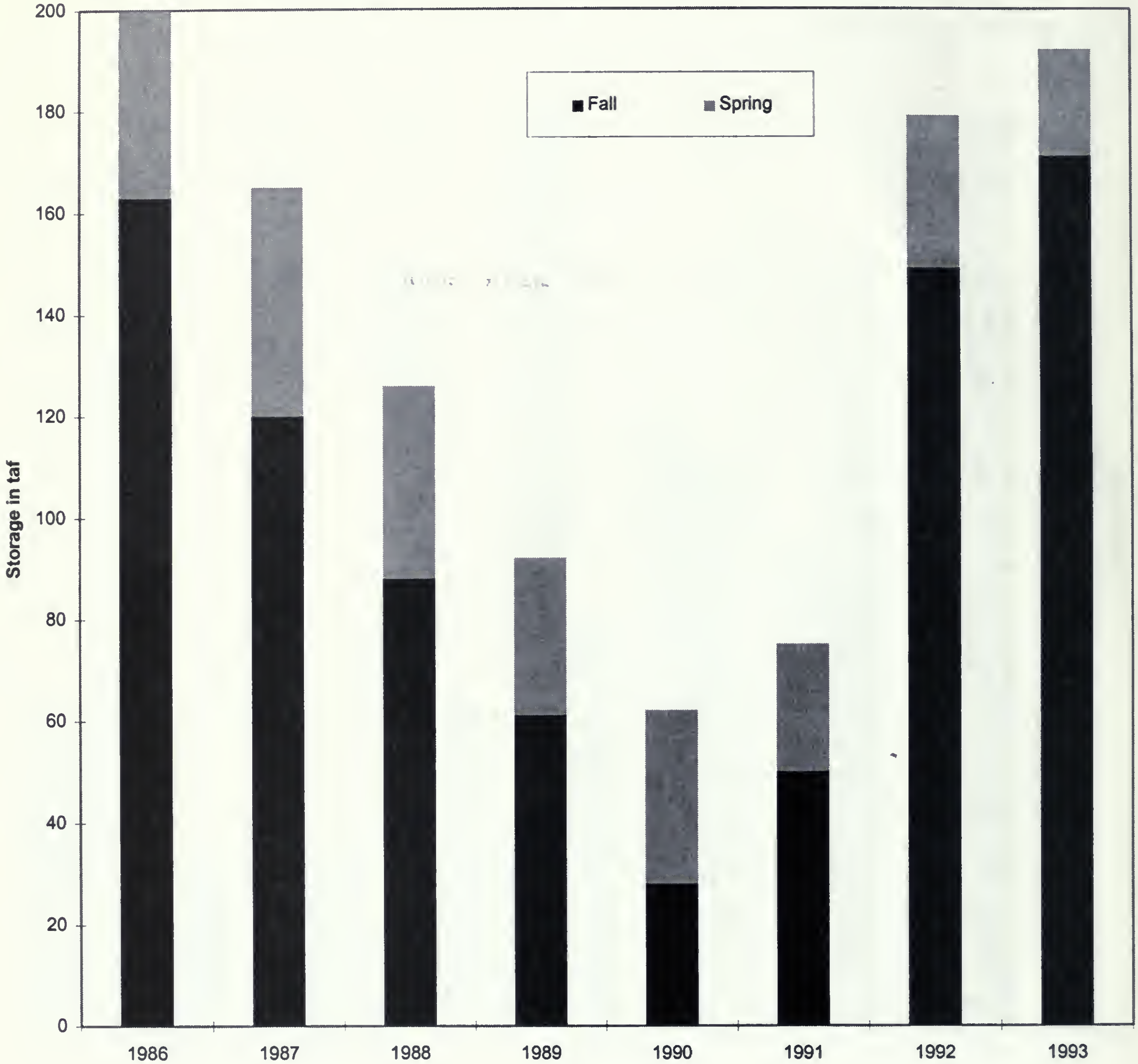


Figure 3-13. Maximum/Minimum Storage During 1987-92 Drought: Cachuma



Surface Water Supplies

Surface Water Development Projects

This section describes California's largest surface water development projects, including the CVP, SWP, Colorado River facilities, and Los Angeles Aqueduct. Descriptions of smaller surface water development projects are provided in Chapters 7-9. See Chapter 1 for a location map of these larger facilities.

☞photo: San Luis Reservoir

Central Valley Project. In 1921, California began planning a water project to serve the Central Valley. The Legislature authorized the State Central Valley Project in 1933. Because California was unable to sell the bonds needed to finance the project during the Great Depression, USBR stepped in to begin project construction. Initial congressional authorization for the CVP covered facilities such as Shasta and Friant dams, Tracy Pumping Plant, and the Contra Costa, Delta-Mendota, and Friant-Kern Canals. Later authorizations included Folsom Dam (1949), Trinity River Division (1955), San Luis Unit (1960), and New Melones Dam (1962).

The USBR's Central Valley Project is the largest water storage and delivery system in California, covering 29 of the state's 58 counties. The project's features include 18 federal reservoirs and 4 additional reservoirs jointly owned with the State Water Project. The keystone of the CVP is the 4.55 maf Lake Shasta, the largest reservoir in California. CVP reservoirs provide a total storage capacity of over 12 maf, nearly 30 percent of the total surface storage in California, and deliver about 7.3 maf annually for agricultural, urban, and wildlife uses. Table 3-4 shows major CVP reservoirs.

Table 3-4. Major Central Valley Project Reservoirs

Reservoir Name	Capacity (taf)	Year Built	Owner	River/Stream
Shasta	4,552	1945	USBR	Sacramento R.
Clair Engle	2,448	1962	USBR	Trinity R.
Whiskeytown	241	1963	USBR	Clear Cr.
Folsom Lake	977	1956	USBR	American R.
New Melones	2,420	1979	USBR	Stanislaus R.
Millerton Lake	520	1947	USBR	San Joaquin R.
San Luis (Federal Share)	971	1967	USBR/DWR	Offstream Storage

Shasta and Keswick reservoirs regulate CVP releases into the Sacramento River. Red Bluff Diversion Dam on the Sacramento River supplies water to the Tehama-Colusa and Corning Canals. At the Delta, CVP water is exported at Rock Slough on the Contra Costa Canal and at Tracy Pumping Plant on the Delta-Mendota Canal. During the winter, water is conveyed via the Delta-Mendota Canal to San Luis Reservoir for delivery to the San Luis and San Felipe units of the project. A portion of the Delta-Mendota Canal export is placed back into the San Joaquin River at Mendota Pool to serve, by exchange, water users with long-standing historical rights to the use of San Joaquin River flow. This exchange enabled the CVP to build Friant Dam, northeast of Fresno, which diverts a major portion of San Joaquin River flows through the Friant-Kern and Madera Canals. A map of CVP facilities is presented in Figure 3-14.

☞photo: Friant Dam

CVP reservoirs also provide flood control.. Shasta and Folsom reservoirs have 1.3 maf and 0.4 maf of federally authorized flood space. Millerton Lake, impounded by Friant Dam, has 170,000 af of rain flood space and up to 520,000 af of snowmelt reservation. New Melones Reservoir has 450,000 af of flood control space.

Figure 3-14. Major CVP Facilities

Auburn Dam -- Planned, But Not Constructed

The proposed Auburn Dam was authorized by Congress in 1965 as an addition to the CVP to provide flood control and water supply on the American River. Foundation preparation and related earthwork for a dam to impound 2.3 maf were halted by seismic safety concerns after the 1975 Oroville earthquake. The dam's design was changed in 1980 from a concrete arch to a gravity structure. The proposed dam has been a source of controversy between proponents of downstream flood control and water supply benefits and those who wish to preserve the American River Canyon. As originally planned, a multi-purpose Auburn Reservoir could have provided more than 0.3 maf per year of new water supply to the CVP, as well as substantial flood control and power benefits. Recent reviews of American River hydrology have emphasized the flood control potential of a dam at Auburn.

Much of the Sacramento metropolitan area is threatened by flooding from the American and Sacramento rivers. The 100-year floodplain covers over 100,000 acres and contains over 400,000 residents, 160,000 homes and structures, and over $37 billion in developed property. When Folsom Dam was completed in 1955, the facility was estimated to provide Sacramento with 250-year level of flood protection. This estimate was revised downward to a 63-year level of protection (85-year level with Folsom reoperation for additional flood control space) after the storms of 1986.

Given the area's low level of flood protection (one of the lowest in the nation for a metropolitan area of its size), the U.S. Army Corps of Engineers has been evaluating many alternatives to providing additional flood protection. Three alternatives that were studied in depth include: (1) the Folsom Modification Plan, (2) the Folsom Stepped Release Plan, and (3) the Detention Dam Plan. The Folsom Modification Plan would increase the maximum flood storage in Folsom from 475,000 to 720,000 af, lower the main spillway by 15 feet, enlarge 8 river outlets, and make levee improvements along the American and Sacramento rivers. The Folsom Stepped Release Plan would increase Folsom's flood storage from 400,000 to 670,000 acre-feet, lower the main spillway by 15 feet, enlarge 8 river outlets, and make necessary levee improvements to increase maximum reservoir releases to 180,000 cfs. The Detention Dam Plan would construct a 508-foot-high flood detention facility on the North Fork of the American River near Auburn, make levee improvements along the American and Sacramento rivers, and return the maximum flood storage in Folsom Reservoir to 400,000 acre-feet.

The USACE completed an EIR/EIS in 1992 and a Supplemental EIR/EIS in March 1996 to address flood control alternatives for the Sacramento area. Both identify the Detention Dam Plan as the National Economic Development plan, i.e. the plan that maximizes the net national economic benefit. In October 1995, the Reclamation Board voted for a preferred plan from among the three alternatives and endorsed the Detention Dam Plan. The Sacramento Area Flood Control Agency also voted for the Detention Dam Plan as the locally preferred plan.

In its Resolution No. 95-17, the Reclamation Board states that it "... believes the Folsom Modification Plan provides an inadequate level of flood protection for the Sacramento area, and would reduce water-supply capacity and hydropower benefits at Folsom Reservoir..." and that "...the Board believes the Stepped Release Plan would place undue reliance on the levees of the lower American River, would reduce water supply capacity and hydropower benefits at Folsom Reservoir, and ... would be significantly more expensive for State and local interests..." Regarding the Detention Dam Plan, the resolution states "... the Board believes that the Detention Dam Plan ... represents the NED Plan for the American River flood plain. The Board recommends that the Corps pursue Congressional authorization of this plan." In spite of support from USACE, the Reclamation Board and SAFCA, the Detention Dam was not authorized in the Water Resources Development Act of 1996.

☞photo: temporary coffer dam failure in 1986 flood

The CVP supplies water to more than 250 long-term water contractors in the service areas shown in Figure 3-15. The majority of CVP water goes to agricultural water users. Urban centers receiving CVP water include Redding, Sacramento, Folsom, Tracy, most of Santa Clara County, northeastern Contra Costa County, and Fresno. Collectively, the contracts call for annual delivery of 9.3 maf, including delivery of 1.4 maf of Friant Division supply available in wet years. Of the 9.3 maf total annual contractual delivery, 6.1 maf is classified as project water and 3.2 maf is classified as water right settlement water. About 90 percent of south-of-Delta contractual delivery is for agricultural uses; the remaining 10 percent is for wildlife refuges. Figure 3-16 shows actual CVP water deliveries since 1960.

Water right settlement water is water covered in agreements with water rights holders whose diversions existed before the project was constructed. Project reservoirs altered natural river flow upon which these pre-project diverters had relied, so contracts were negotiated to provide stored water to these users. CVP water right settlement contractors on the upper Sacramento River receive their supply (about 2.2 maf per year) from natural flow and storage regulated at Shasta Dam. Settlement contractors on the San Joaquin River (called exchange contractors) receive Delta water via the Delta-Mendota Canal.

Thanks to the substantial generation capacity of its Shasta-Trinity complex, the CVP has been the State's largest net producer of electric power. The project's average annual electric power generation is 5.0 billion kWh and its average annual energy usage is 1.3 billion kWh. Figure 3-17 shows CVP hydroelectric energy production since 1960. Power generated by the CVP is marketed by the Western Area Power Administration.

The capability of the CVP to deliver full water supply requests by its south-of-Delta contractors in a given year depends on rainfall, snowpack, runoff, water in storage, pumping capacity from the Delta, and regulatory constraints on CVP operation. Figure 3-18 shows existing (1995 level) and future (2020 level) CVP south-of-Delta delivery capability, as estimated by operations studies, under SWRCB Order WR 95-6. The figure shows that existing CVP facilities have a 20 percent chance of making full deliveries under both demand levels.

Figure 3-15. Central Valley Project Service Areas

Figure 3-16. CVP Deliveries 1960-96

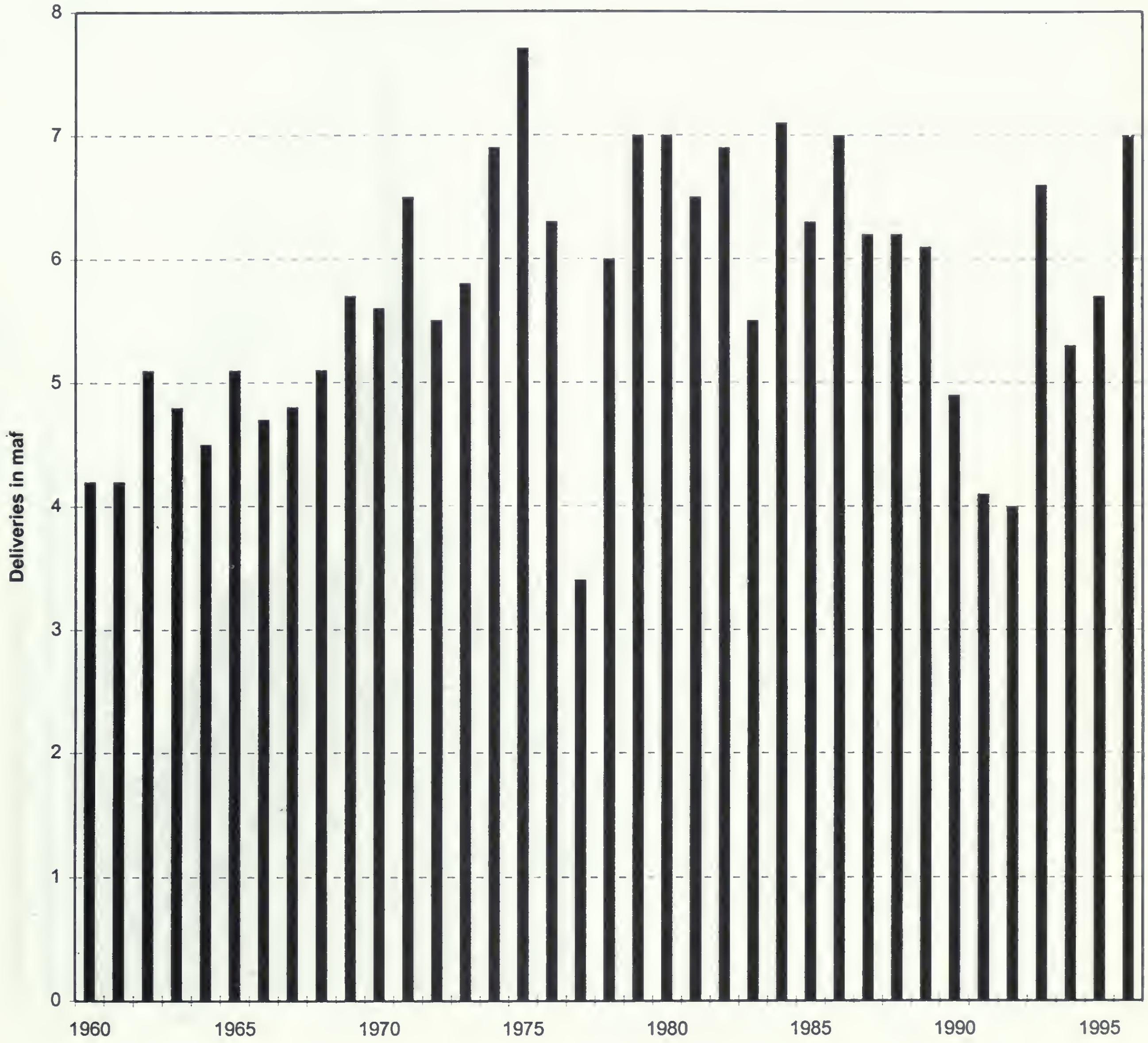


Figure 3-17. CVP Power Generation

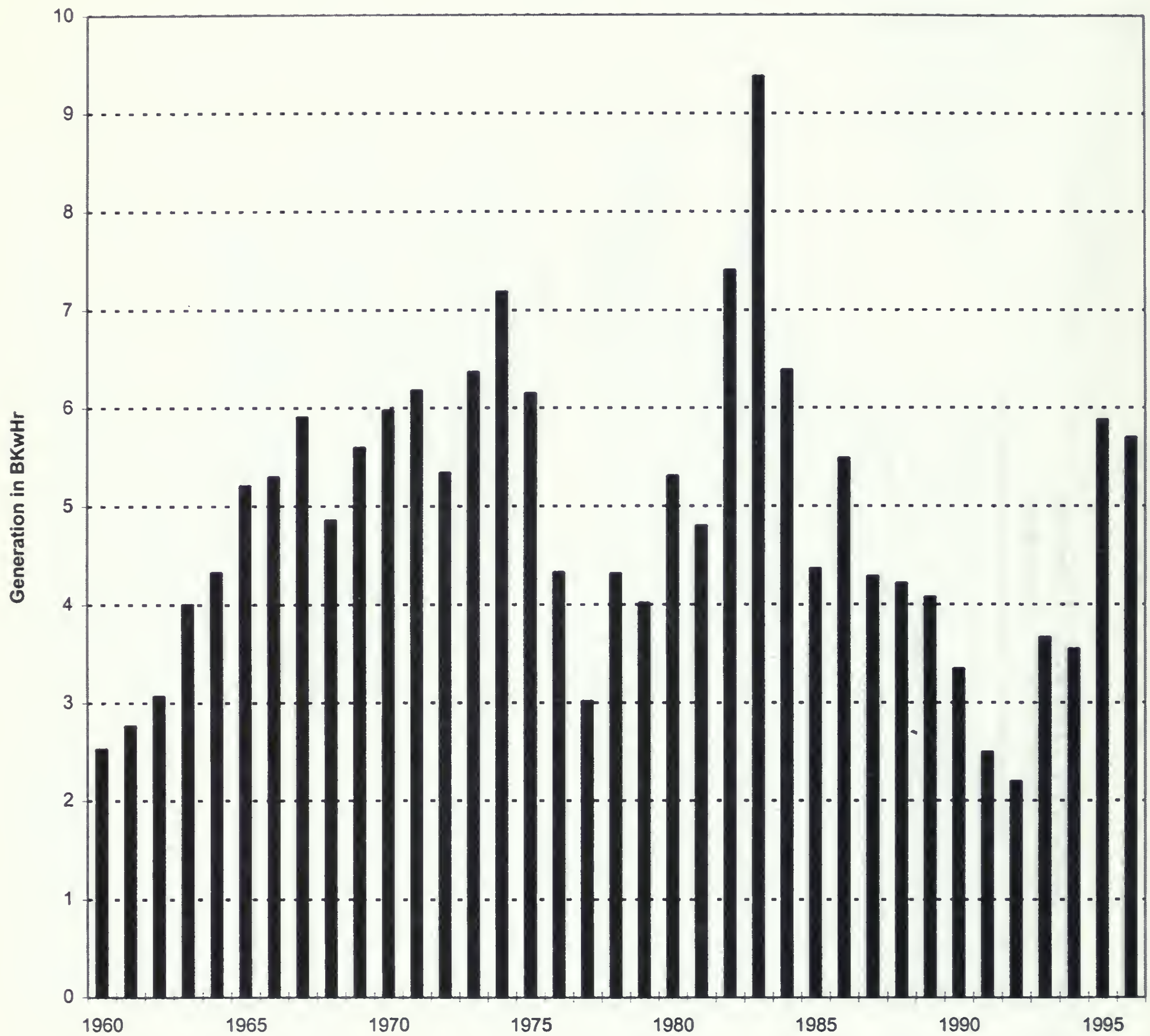
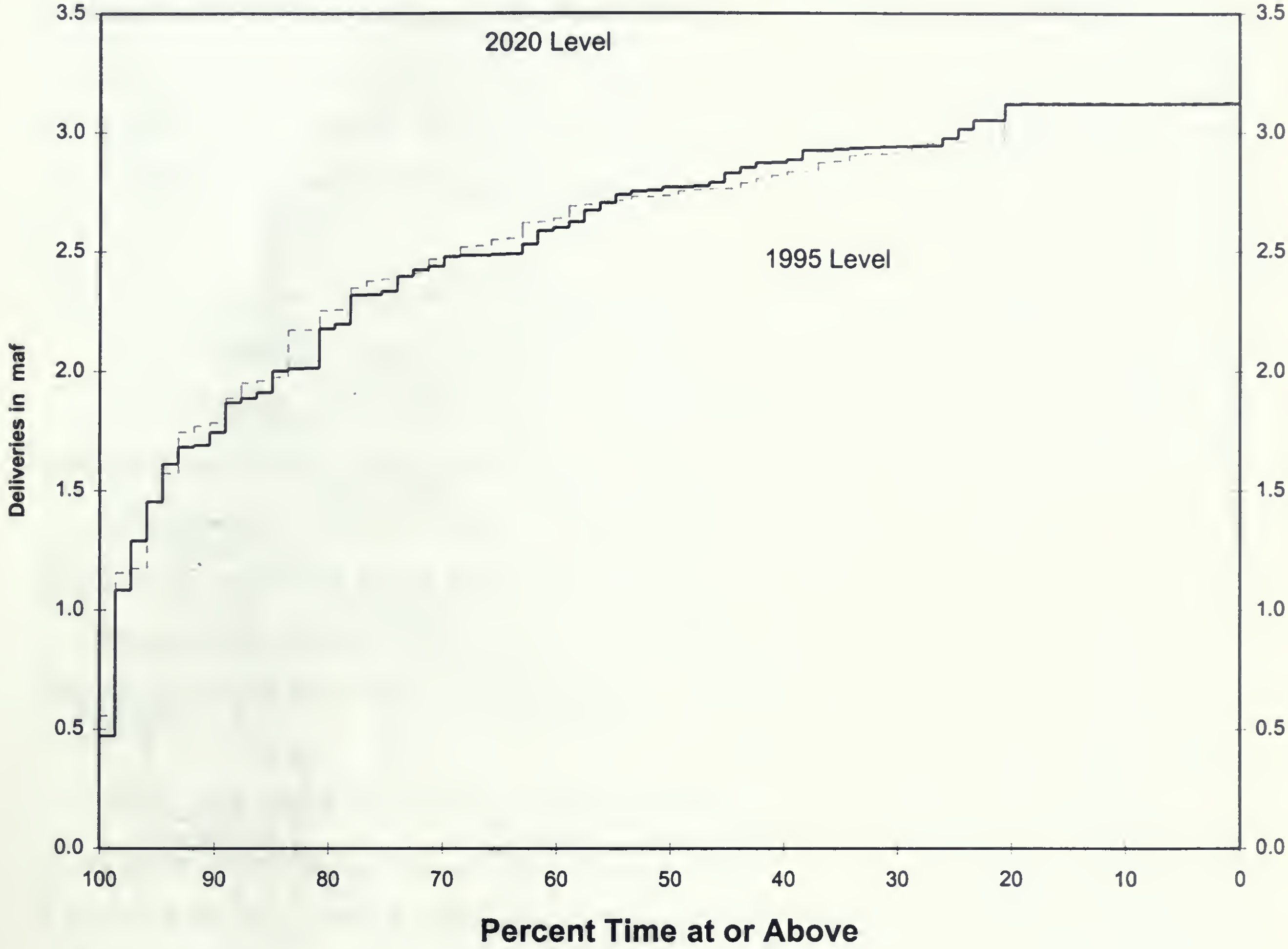


Figure 3-18. 1995 and 2020 Level CVP Delivery Capability South of Delta with Existing Facilities



The State Water Project. It was evident soon after World War II that local and federal water development could not keep pace with California's rapidly growing population. Planning for the multipurpose SWP began in the late 1940s, and accelerated in the early 1950s. Voters authorized SWP construction in 1960 by ratifying the Burns-Porter Act. The majority of existing project facilities were constructed in the 1960s and 1970s. Future SWP facilities were to be added as water demands increased, to meet the project's initial contracted entitlement of 4.2 maf per year.

SWP facilities include 20 dams, 662 miles of aqueduct (both canal and pipeline sections), and 26 power and pumping plants. SWP reservoirs are listed in Table 3-5. Major facilities include the multipurpose Oroville Dam and Reservoir on the Feather River, the Edmund G. Brown California Aqueduct, South Bay Aqueduct, North Bay Aqueduct, and a share of the State-federal San Luis Reservoir. With a storage capacity of 3.5 maf, Lake Oroville is the second largest reservoir in California after Lake Shasta. Oroville stores winter and spring flows of the upper Feather River. Water released from Oroville travels down the Feather and Sacramento rivers to the Delta. There, water is pumped into the California Aqueduct for delivery to the San Joaquin Valley and Southern California.

Water is also diverted into the South Bay Aqueduct, which extends into Santa Clara County. A separate Delta diversion supplies the North Bay Aqueduct, which serves areas in Napa and Solano counties. Maximum capacity of the California Aqueduct is 10,300 cfs at the Delta and 4,480 cfs over the Tehachapis to the South Coast Region. The Department has just completed construction of the Coastal Branch of the California Aqueduct, which extends about 115 miles from the main aqueduct to serve parts of San Luis Obispo and Santa Barbara counties. A map of SWP facilities is presented in Figure 3-19.

Figure 3-19. Major SWP Faclities

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Table 3-5. Major State Water Project Reservoirs

Reservoir Name	Capacity (taf)	Year Built	Owner	River/Stream
Oroville	3,538	1968	DWR	Feather R.
Del Valle	77	1968	DWR	Arroyo Valle Cr.
Silverwood	73	1971	DWR	Regulatory Terminal Storage
Castaic	324	1973	DWR	Terminal Storage
Frenchman	55	1961	DWR	Last Chance Cr.
Davis	84	1966	DWR	Big Grizzly Cr.
Perris	131	1973	DWR	Terminal Storage
Pyramid Lake	171	1973	DWR	Piru Cr.
San Luis (State Share)	1,068	1967	DWR/USBR	Offstream Storage

The project's average annual electric power generation is 7.6 billion kWh, and its average annual energy usage is 12.2 billion kWh. The SWP is the single largest power user in California, and is the state's fourth largest generator of electrical energy.

☞photo: Bluestone PP

The service area of the 29 SWP contracting agencies is shown in Figure 3-20. Initial project contracts were signed for an eventual annual delivery of 4.2 maf. Of this annual entitlement, about 2.5 maf was to serve southern California and about 1.3 maf was to serve the San Joaquin Valley. The remaining 0.4 maf annual entitlement was to serve the Feather River area, and the San Francisco Bay and Central Coast regions. (As discussed in Chapter 2, 45,000 af of annual entitlement belonging to two project contractors was subsequently retired as part of the Monterey Agreement.) Figure 3-21 depicts a history of SWP water deliveries since 1967. Generally, San Joaquin Valley use of SWP supply has been near full contract amounts since about 1980 (except during very wet years and during deficient-supply years), whereas southern California use has reached about 60 percent of full entitlement.

The ability of the SWP to deliver full water supply requests by its contractors in a given year depends on rainfall, snowpack, runoff, water in storage, pumping capacity from the Delta, and regulatory constraints on SWP operation. The calculated average annual delivery during a repeat of the 1928-34 drought is about 2.1 maf per year. About half of this water comes from Lake Oroville and the rest from surplus flow in the Delta, some of which is stored in San Luis

Reservoir. Figure 3-22 shows existing (1995 level) and future (2020 level) SWP delivery capability, as estimated by operations studies, under SWRCB Order WR 95-6. The figure shows that existing SWP facilities have a 65 percent chance of making full deliveries under 1995 level demands and have an 85 percent chance of delivering 2.0 maf to project contractors in any given year. The figure also shows that under a more stringent 2020 level demand scenario, existing SWP facilities have a decreased chance of making full deliveries.

Figure 3-20. State Water Project Service Areas

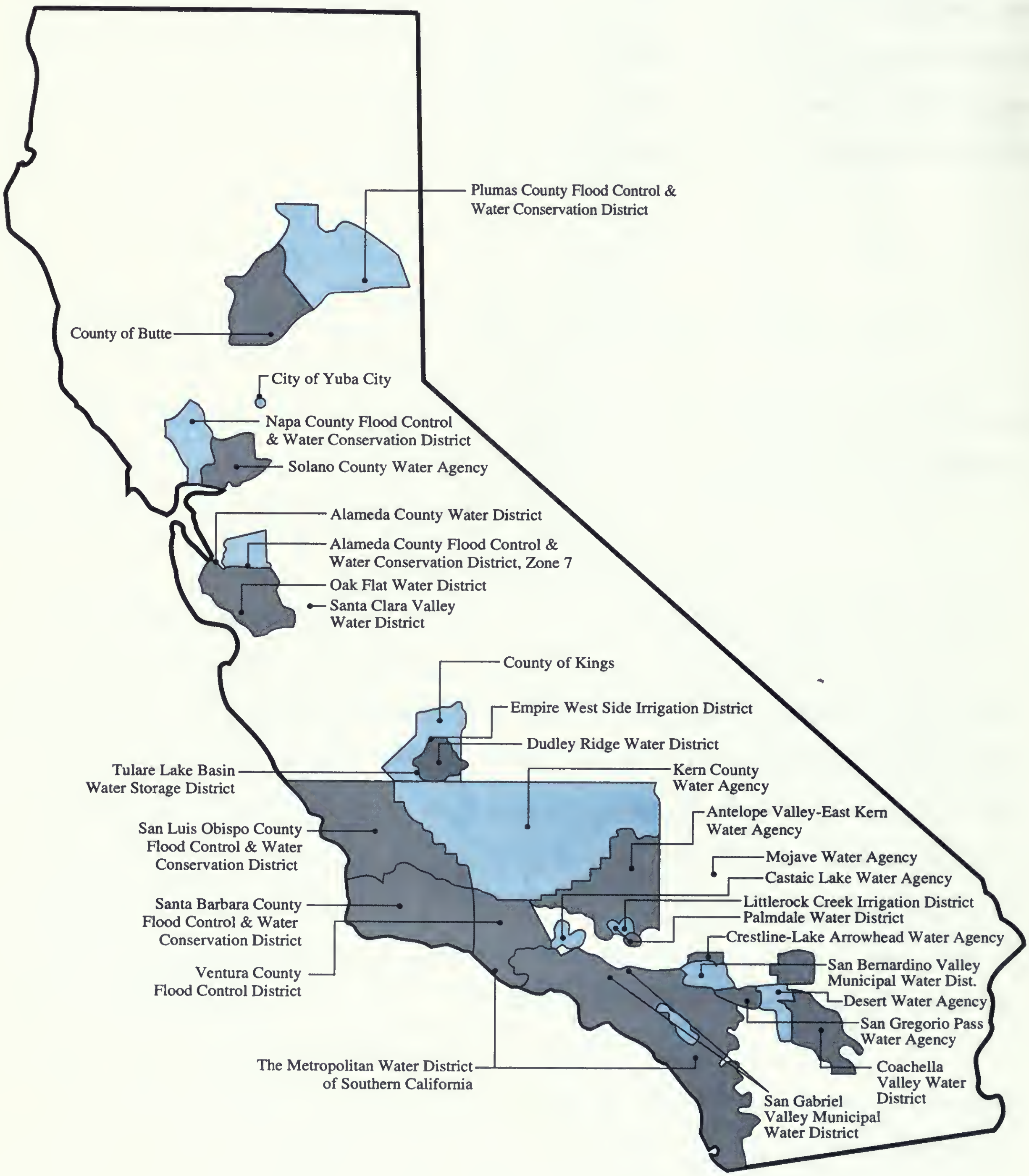


Figure 3-21. SWP Deliveries

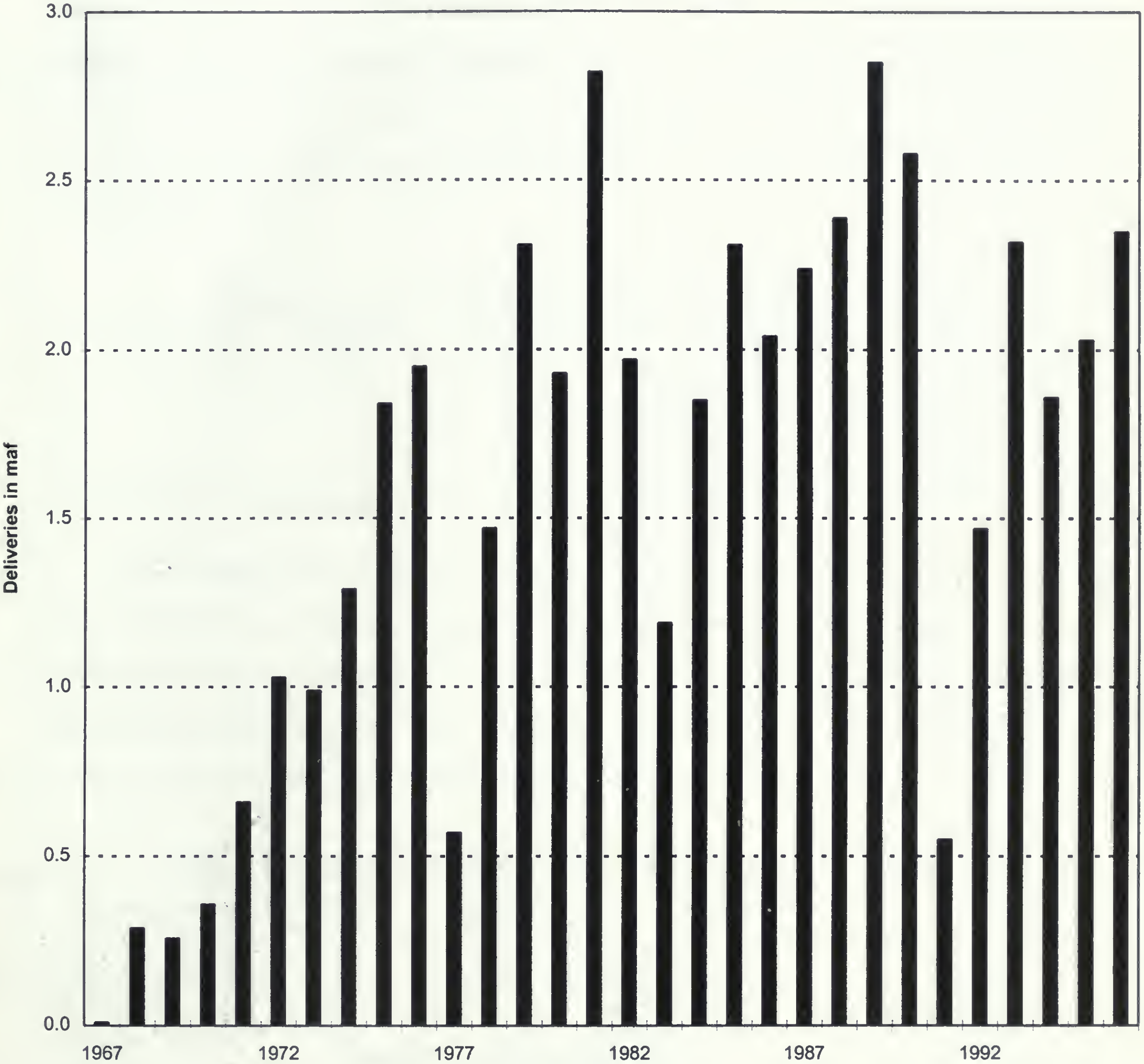
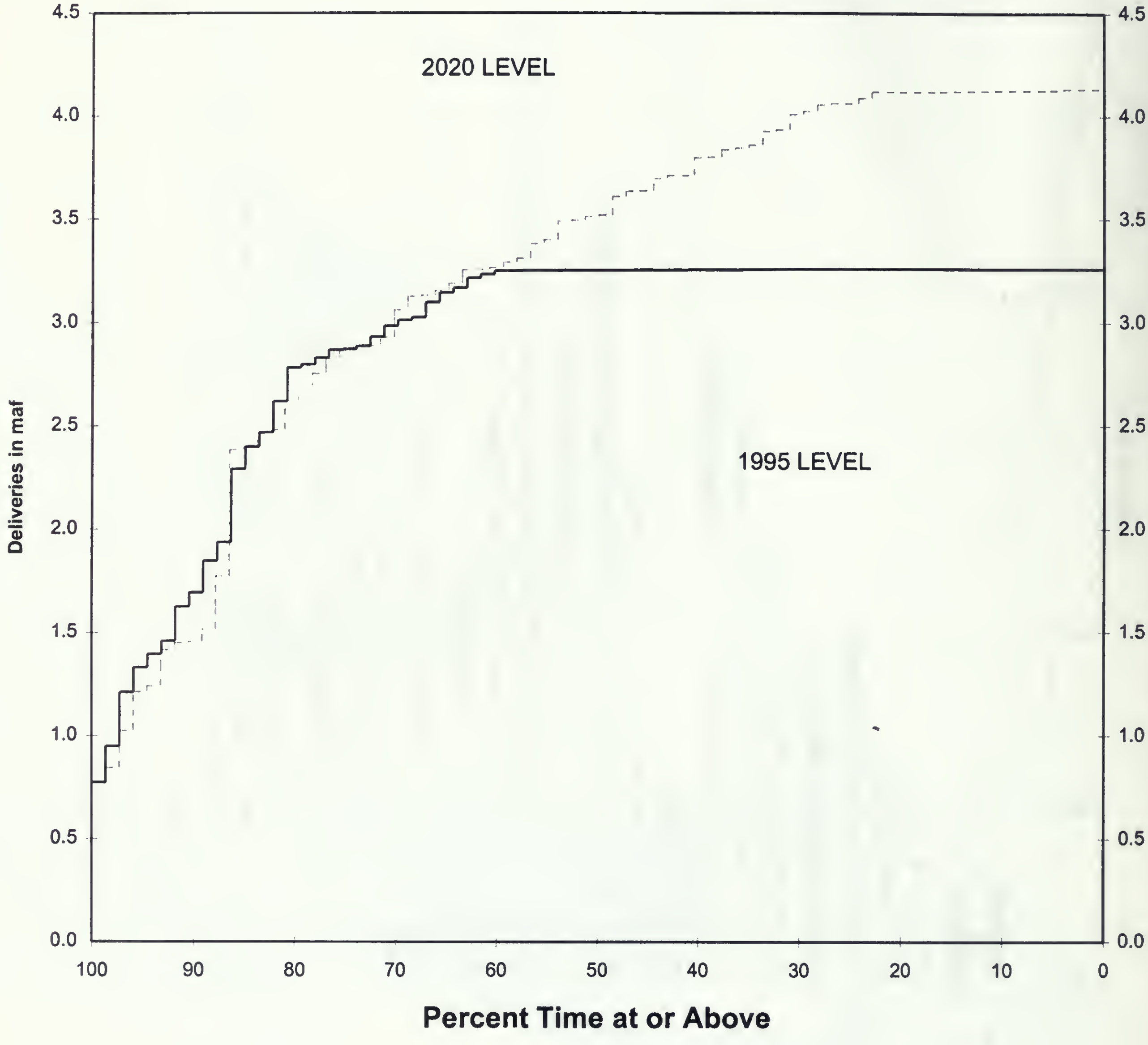


Figure 3-22. 1995 and 2020 Level SWP Delivery Capability with Existing Facilities



Klamath Project. The USBR's Klamath project straddles the California-Oregon state line near Klamath Falls, Oregon. The project, authorized in 1905 by the Reclamation Act of 1902, transfers water between the Lost River (which naturally flowed into Tule Lake) and the Klamath River. The Klamath Project transformed about 225,000 acres of rangeland, including a portion of the former Tule Lake, into irrigated farmland. Major storage facilities on the Klamath River are given in Table 3-6.

Table 3-6. Major Storage Facilities on the Klamath River

Reservoir Name	Capacity (taf)	Year Built	Owner	River/Stream
Clear	527	1910	USBR	Lost R.
Gerber	94	1925	USBR	Miller Cr.
Upper Klamath	873	1921	Pacific Power & Light	Klamath R.

The Klamath project includes 185 miles of main canal, 532 miles of laterals, 37 pumping plants, and 728 miles of drains. Estimated project agricultural water use has historically been about 400,000 af/year. The project furnishes water to the Lower Klamath, Clear Creek, and Tule Lake national wildlife refuges. Water deliveries remained relatively constant until project operational changes were recently made to protect ESA-listed fish species.

Table 3-7. Storage Facilities of Other Federally Owned Water Projects

Reservoir Name	Capacity (taf)	Year Built	Owner	River/Stream
Sonoma	381	1982	USACE	Dry Cr.
New Hogan	317	1963	USACE	Calaveras R.
Berryessa	1,600	1957	USBR	Putah Cr.
Cachuma	205	1953	USBR	Santa Ynez R.
Casitas	254	1959	USBR	Ventura R.
East Park	51	1910	USBR	Stony Cr.
Stony Gorge	50	1928	USBR	Stony Cr.
Lake Tahoe[1]	745	1913	Sierra Pacific Power Company[2]	Truckee R.
Prosser Creek[1]	30	1962	USBR	Prosser Cr.
Stampede Reservoir[1]	227	1970	USBR	Little Truckee R
Boca Reservoir[1]	41	1937	USBR	Little Truckee R.

1 Lands served by the reservoir as located in Nevada.

2 USBR controls the dam under easement from Sierra Pacific Power Company.

Colorado River. The Colorado River is an interstate and international river. Its mean annual unimpaired flow is about 14 maf. The river, which has its headwaters in Wyoming's Green River basin, crosses seven states before flowing into Mexico and terminating at the Gulf of California. The Colorado River watershed is depicted in Figure 3-23.

Nearly 60 maf of surface water storage has been developed on the river and its tributaries upstream of Hoover Dam, resulting in a ratio of storage to average annual river flow of about 4 to 1 -- much higher than the ratio found on most of California's intrastate rivers. The two largest reservoirs are the 27 maf Lake Powell (impounded by Glen Canyon Dam) and the almost 30 maf Lake Mead (impounded by Hoover Dam). Three dams divert water from the Colorado River to California. Parker Dam, which impounds Lake Havasu, supplies water for MWD's Colorado River Aqueduct and for Arizona's Central Arizona Project. Palo Verde Diversion Dam supplies water to Palo Verde Irrigation District's canal system. Imperial Dam supplies water for the All-American Canal, Bard Water District, and Quechan Indian Tribe's reservation. An off-stream storage reservoir, Senator Wash Reservoir, is used to adjust releases between Parker Dam and downstream demands. The Colorado River service area is shown in Figure 3-24.

☞photo: All American Canal

Figure 3-23. Colorado River Watershed

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Figure 3-24. Colorado River Service Areas

Two major facilities, USBR's All American Canal and MWDSC's Colorado River Aqueduct, convey Colorado River water. Construction of the All American Canal was authorized in the 1928 Boulder Canyon Project Act. Work on the canal began in the 1930s, with first water deliveries occurring in 1940. Colorado River water diverted at Imperial Dam flows by gravity through the All American Canal and the Coachella Canal to agricultural areas in the Imperial and Coachella valleys. The All American Canal has a maximum capacity of 15,200 cfs in the reach immediately downstream from Imperial Dam. The main branch of the All American Canal extends 82 miles from Imperial Dam to the western portion of Imperial Irrigation District's distribution system. The Coachella Canal branches off from the main canal and extends 122 miles northward, to terminate in Coachella Valley Water District's Lake Cahuilla.

In 1933, MWDSC started constructing an aqueduct to divert Colorado River water from Lake Havasu to the South Coast Region. Completed in 1941, the 242-mile long aqueduct had a design capacity of 1.2 maf per year, although MWDSC has been able to deliver as much as 1.3 maf per year. Facilities associated with the aqueduct include five major pumping plants and Lake Matthews, the aqueduct's terminal reservoir in Riverside County. The San Diego Aqueduct, constructed by the federal government, interconnects with the Colorado River Aqueduct in Riverside County. Delivery of Colorado River Aqueduct water to San Diego County began in 1947.

California's basic apportionment of Colorado River supplies is a consumptive use of 4.4 maf per year, plus half of any excess or surplus water. Apportionment of the Colorado River supplies is discussed in detail in Chapter 9 and Colorado River operations are described in the following sidebar. California has been able to use up to 5.3 maf of Colorado River supplies annually because several wet winters occurred in the 1980s and 1990s, Arizona and Nevada were not yet using their full apportionment, and surplus water was available. Since 1980, the highest and the lowest recorded annual natural runoffs were recorded on the Colorado River, with the highest occurring in 1984 and the lowest occurring in 1990.

Colorado River Operations

Operations of the Colorado River are controlled by the USBR, which in effect serves as the watermaster for the river. USBR maintains an accounting of consumptive use of the basin states' allocations, and ensures that Mexican treaty requirements are met with respect to the quantity and salinity concentration of water delivered to Mexico.

The 1968 Colorado River Basin Project Act directed DOI to develop criteria for long-range operation of the major federal reservoirs on the river and its tributaries. USBR conducts a formal review of the long-range operating criteria every five years. The Act further requires DOI to prepare an annual operating plan for the river, in consultation with representatives from the basin states. Some river operating criteria have already been established in the statutes comprising the law of the river (see Chapter 9 for more detail). For example, USBR is required to equalize, to the extent practicable, storage in Lake Mead and Lake Powell. (Lake Powell in essence serves as the bank account that guarantees annual delivery of 7.5 maf from the Upper Basin to the Lower Basin, plus water to satisfy Mexican treaty obligations. The actual statutory guarantee is 75 maf every 10 years, plus one-half of any deficiency in Colorado River supplies, to permit the U.S. to satisfy its treaty obligation to Mexico.)

Current federal operating criteria for the river have focused on avoiding flood control releases, in response to the wet hydrologic conditions experienced on the river in the 1980s. As consumptive use of water in the Lower Basin approaches the 7.5 maf basic apportionment, there has been increasing interest in operating the river more efficiently from a water supply standpoint. Proposals discussed among Colorado River water users have included a variety of surplus and shortage operating criteria, banking programs, and augmentation of the river's base flow.

USBR declared a surplus condition on the river in 1996 and 1997, allowing California to continue diverting more than its basic apportionment without penalty. In 1997, flood control releases were made from Lake Mead. Flood control releases are forecasted for 1998.

Other Federal Projects. In addition to the CVP and Klamath Project, USACE, and USBR have constructed numerous other federal water projects in California (see Table 3-7). These projects provide important flood control and recreation benefits and deliver about 0.9 maf (including Klamath Project deliveries) of water supply annually.

Los Angeles Aqueduct. In 1913, the city of Los Angeles began importing water from the Owens Valley through the first pipeline of the Los Angeles Aqueduct. An engineering landmark, the original aqueduct reach is 233 miles long, has 142 tunnels, and crosses nine major canyons to deliver water to Los Angeles using only the force of gravity. In 1940, the first pipeline of the aqueduct was extended north to tap the water of the Mono Basin at Lee Vining Creek, increasing the length of the first barrel to 338 miles. The extension includes an 11-mile tunnel that was drilled through the Mono Craters.

To keep pace with the city's growing population, the second pipeline of the Los Angeles Aqueduct was completed in 1970 to import additional water from the southern Owens Valley at Haiwee Reservoir. The second barrel increased the Aqueduct's delivery capacity from 330 taf per year to 480 taf per year. In dry years, the Aqueduct was to be maintained at full capacity through groundwater pumping in the Owens Valley. In addition to the two aqueduct pipelines, the system includes seven reservoirs and eleven powerplants. The largest reservoirs are shown in Table 3-8.

Table 3-8. Larger Reservoirs in Los Angeles Aqueduct System

Reservoir Name	*Capacity (taf)*	*Year Built*	*Owner*	*River/Stream*
Grant Lake	48	1940	LADWP	Rush Cr.
Crowley Lake	184	1941	LADWP	Owens R.
Tinemaha	16	1928	LADWP	Owens R.
Haiwee	39	1913	LADWP	Rose Valley Cr.
Bouquet	34	1934	LADWP	Bouquet Cr.

The delivery capability of LADWP's aqueduct system has been affected by judicial and regulatory actions intended to restore environmental resources in the Mono Lake basin and in the Owens River Valley. In 1979, the National Audubon Society, the Mono Lake Committee, and others filed the first in a series of lawsuits which challenged the project's water diversions from the Mono Basin. In 1989 and 1990, the El Dorado County Superior Court entered preliminary injunctions which required the project to reduce diversions to restore and maintain the water level of Mono Lake at 6,377 feet, and established minimum fishery flows in all four Mono Basin streams from which project diversions are made.

In 1994, SWRCB's Decision 1631 specified minimum fishery flows on the four Mono Basin streams. The order also established water diversion criteria to protect wildlife and other environmental resources in the Mono Basin. The water diversion criteria prohibited export of water from the Mono Basin until the water level of Mono Lake reaches 6,377 feet, and restricted Basin exports to allow the water level of Mono Lake to rise to an elevation of 6,391 feet in approximately 20 years. Once the water level of 6,391 feet is reached, the Los Angeles Aqueduct will be able to export approximately 31 taf per year from the Mono Basin.

☞photo: Mono Lake(with tufa towers)

Longstanding litigation between Inyo County and the city of Los Angeles over environmental effects of Owens Valley groundwater pumping ended in June 1997, allowing implementation of water management and environmental mitigation actions that had been planned for the valley. (See Chapter 9 for additional details.) A key environmental restoration effort is rewatering the lower Owens River in a 60 mile stretch from the aqueduct intake south of Big Pine to just north of Owens Dry Lake. The effort calls for providing continuous river flows of about 40 cfs (with seasonal habitat flows up to about 200 cfs), establishing 1,825 acres of wetlands, and establishing and maintaining off-river lakes and ponds. (Most of the instream flows will be pumped back out of the river and into the Los Angeles aqueduct from a point just north of Owens Dry Lake. Between 6 and 9 cfs will be allowed to flow past the pumpback station to sustain a 325 acre wetland in the Owens Lake delta.) Providing the base flow of 40 cfs and river channel restoration must begin no later than 2003.

As discussed in Chapter 9, the Great Basin Unified Air Pollution Control District issued an order to LADWP in July 1997 that would require 50 taf of water per year to control dust from the Owens Dry Lake. Two potential sources of water identified by the GBUAPCD include aquifers under the lake bed and the Los Angeles Aqueduct. It is expected that LADWP will appeal the order, which has not yet been adopted by the Air Resources Board.

Tuolumne River Development. The Tuolumne River, which begins at Lyell Glacier in Yosemite National Park and extends 163 miles to the confluence with the San Joaquin River west of Modesto, is the largest of the San Joaquin River tributaries. It produces an average annual runoff of about 1.9 maf of which 1.2 maf comes from snowmelt runoff between April and July. Total reservoir capacity on the river is 2.8 maf, almost 1.5 times its average annual runoff. Of this total, over 0.34 maf is reserved for control of winter rain floods. Table 3-9 lists major reservoirs on the Tuolumne River.

Table 3-9. Larger Reservoirs in the Tuolumne River Basin

Reservoir Name	*Capacity (taf)*	*Year Built*	*Owner*	*River/Stream*
New Don Pedro	2,030	1971	Turlock ID	Tuolumne R.
Hetch Hetchy	360	1923	San Francisco	Tuolumne R.
Lake Lloyd	269	1956	San Francisco	Cherry Cr.
Eleanor	28	1918	San Francisco	Eleanor Cr.
Turlock	49	1915	Turlock ID	Offstream
Dallas Warner	29	1911	Modesto ID	Offstream

☞photo: New Don Pedro spilling in 1997

The oldest dam on the Tuolumne River is La Grange Dam about 2.5 miles downstream of New Don Pedro Dam. The 131 feet high La Grange Dam was completed in 1894; it serves as a diversion dam to divert river flows into Modesto ID's and Turlock ID's canals. In 1923, Modesto and Turlock irrigation districts completed the old Don Pedro concrete dam with a capacity of around 0.29 maf. The New Don Pedro Dam, capacity 2.03 maf, was completed in 1971 as a joint project of the two irrigation districts and the city and county of San Francisco.

☞photo: SF water temple

In its early years, the City of San Francisco's water supply came from local creeks and springs. This was soon inadequate and water from the peninsula was drawn from Pilarcitos Creek in San Mateo County in 1862, via a tunnel and redwood flume. In the 1870s, San Andreas and Crystal Springs reservoirs were added and, with later improvements, increased the city's water supply greatly. About the turn of the century, the Spring Valley Water Company, the city's main water purveyor, turned its attention to the East Bay area and Alameda Creek. It constructed the Sunol Aqueduct in 1900 and completed Calaveras dam in 1925. (The 215 feet high dam was the highest earth-fill dam in the world at the time.)

Concern about adequate water supply led to a series of studies and the choice in 1901 of the Tuolumne River as the major source of supply. The centerpiece was to be a dam at Hetch Hetchy Valley in northern Yosemite Park. Authorization was secured in the 1913 Raker Act and work soon began on the construction of O'Shaughnessy Dam and the Hetch Hetchy Aqueduct. A dam at Lake Eleanor was built in 1917 to supply hydroelectric power for Hetch Hetchy construction. O'Shaughnessy Dam was completed in 1923 and the San Joaquin Valley pipeline and Coast Range tunnel were finished and delivered the first water to the San Francisco peninsula in 1934. Cherry Valley Dam (Lake Lloyd Reservoir) was completed in 1956, which added further regulated storage to help satisfy irrigation district prior water rights below Hetch Hetchy.

The capacity of the current Hetch Hetchy Aqueduct system's San Joaquin pipeline is around 0.33 maf per year. Current diversions are around 0.25 maf. A reevaluation of dependable supply based on the capability during the 1987-92 drought has lowered firm yield to around 0.27 maf per year.

Two major San Joaquin Valley irrigation districts, Turlock and Modesto irrigation districts, have water rights on the Tuolumne River that are senior to those of San Francisco. Annual diversions by these irrigation districts have averaged about 0.90 maf. As shown in Table 3-9, each of the irrigation districts uses an offstream regulatory reservoir to manage the distribution of the water diverted from the river.

Mokelumne Aqueduct. The Mokelumne River, one of the smaller Sierra Nevada rivers, has an average annual runoff of 0.74 maf. It is a snowmelt stream, with over 60 percent of its runoff occurring during April through July. The Mokelumne River has about 0.84 maf of storage capacity, approximately 1.1 times its average annual runoff. The largest reservoir is Camanche, which can hold 417,000 af. Total flood control space on the Mokelumne River system is 200,000 af. In addition to EBMUD's facilities on the river (see Table 3-10), there are storage and diversion works for two irrigation districts -- Jackson Valley and Woodbridge Irrigation Districts.

Table 3-10. Mokelumne River Aqueduct System Reservoirs

Reservoir Name	*Capacity (taf)*	*Year Built*	*Owner*	*River/Stream*
Camanche	431	1963	EBMUD	Mokelumne R.
Pardee	210	1929	EBMUD	Mokelumne R.

In the 1920s, as the Hetch Hetchy Project for the San Francisco peninsula was underway, the East Bay cities of the San Francisco Bay region also turned to the Sierra Nevada for more water, specifically to the Mokelumne River. EBMUD completed Pardee Dam and the Mokelumne Aqueduct from Pardee Reservoir to the East Bay in 1929. The downstream Camanche Reservoir was completed in 1963. With the addition of a third barrel, Mokelumne Aqueduct capacity was increased from 224,000 af per year to 364,000 af per year in 1965. Drought year supplies are not always adequate to sustain full aqueduct capacity diversions.

Yuba and Bear Rivers Development. The Yuba and Bear rivers drain the west slope of the Sierra Nevada between the Feather River basin on the north and the American River basin on the south. The Yuba and Bear river basins include portions of Yuba, Sutter, Placer, Nevada, Sierra, Butte, and Plumas counties. Elevations range from 60 feet near Marysville to over 9,000 feet along the Sierra Nevada crest. The basins produce an average annual runoff of about 2.4 maf, 45 percent of which is derived from snowmelt from April through July. Runoff from the 1,700 square mile area drains westerly to the confluence with the Feather River, south of Marysville. Total reservoir capacity on the rivers is more than 1.6 maf, or approximately two-thirds of the average annual runoff. Surface water development provides municipal, irrigation, power generation, and environmental supplies to more than one dozen water purveyors, the cities of Marysville, Grass Valley, Nevada City, and many smaller communities.

The basins contain numerous lakes and reservoirs, including many small mountain lakes in the headwaters area. The larger reservoirs are listed in Table 3-11. New Bullards Bar, a concrete arch dam 645 feet high impounding a 970,000 af reservoir, is located on the North Fork Yuba River about 30 miles northeast of Marysville. The facility was built for irrigation, power generation, recreation, fish and wildlife enhancement, and flood control. Seasonal flood control storage capacity is 170,000 af. Englebright Dam (also known as Narrows Reservoir) was constructed in 1941 by the California Debris Commission as a debris storage project. The dam, along with Daguerre Point Dam and channel training walls farther downstream, was designed to control movement of hydraulic mining debris along the lower Yuba River. Up to that time, mining debris was filling the downstream channels, creating flooding and navigation problems. Currently, PG&E and YCWA pay the federal government to use Englebright's storage to generate hydroelectric power at two power plants.

Table 3-11. Larger Reservoirs along the Yuba and Bear Rivers

Reservoir Name	Capacity (taf)	Year Built	Owner	River/Stream
New Bullards Bar	970	1970	YCWA	NF Yuba R.
Camp Far West	103	1963	South Sutter WD	Bear R.
Lake Spaulding	75	1913	PG&E	SF Yuba R.
Jackson Meadows	69	1965	Nevada ID	MF Yuba R.
Rollins	66	1965	Nevada ID	Bear R.
Englebright	70	1941	USACE	Yuba R.
Scotts Flat	49	1948	Nevada ID	Deer Cr.
Bowman	69	1927	Nevada ID	Canyon Cr.

☞photo: hydraulic mining

Water in the Yuba and Bear rivers is transferred to both the Feather and American river basins via diversion works. Water is transferred to the Feather River basin (from Slate Creek to Sly Creek Reservoir) by Oroville-Wyandotte Irrigation District. Water is transferred to the American River basin (from Rollins Reservoir to Folsom Lake) by PG&E and Nevada Irrigation District. PG&E also diverts water for power generation from the American River basin to the Bear River, which is subsequently returned to the North Fork American River and Folsom Lake.

Reservoir and River Operations

Most large reservoirs in California are multipurpose impoundments designed to provide water supply storage, electric power, flood control, recreation, water quality, and downstream fishery needs. Often the large reservoirs would not exist as single purpose projects; the cost would be too great. Multipurpose designs maximize the beneficial uses large reservoir sites.

Water Supply Operations. Water supply needs dictate many operating criteria of multipurpose reservoirs. Sufficient water must be provided for existing water rights, in-stream requirements for fish and water quality (including temperature control), downstream water demands, and, in the case of Shasta Reservoir, minimum flows or depths in the Sacramento River for navigation. The generation of hydroelectric power is, for the most part, an ancillary purpose. However, where there is capacity and an afterbay to re-regulate flow, reservoirs may be operated to meet peaking power needs. Lake recreation is an important element of the local economy at many reservoirs. High reservoir levels often are maintained into the summer to maximize local recreation.

Urban and agricultural water demands are highest during the summer and lowest during winter, the inverse of natural runoff patterns. Environmental water demands can follow a different pattern. Water needs for flooding refuge and duck club lands tend to peak in the late fall. Anadromous fishery (primarily salmon) demands are highest in the fall to attract spawning fish and again in the spring to move the newly hatched smolts and fry downstream to the ocean. Demands for groundwater recharge can be scheduled any time of the year when water spreading capacity is available. Reservoir operators must balance these varying water demands against other considerations that affect reservoir and river use, such as flood control operating criteria and fishery temperature needs.

Flood Control Operations. For any reservoir designed to provide flood control benefits, USACE rules control reservoir levels during the flood season to maintain safe storage reservations. Flood control storage in major Central Valley reservoirs is listed in Table 3-12. Operating rules set by USACE guide how water is stored in the reservoir during the flood control season and how flood control releases are handled, as described in the following sidebar.

Table 3-12. Federal Flood Control Storage in Major Central Valley Reservoirs

Project Name	Stream	Storage (taf)	Maximum Flood Control Space (taf)	Owner
Shasta Lake	Sacramento River	4,552	1,300	USBR
Lake Oroville	Feather River	3,538	750	DWR
Black Butte Lake	Stony Creek	144	137[1]	USACE
New Bullards Bar Res.	Yuba River	966	170	YCWA
Indian Valley Res.	Cache Creek	301	40	YCFCWCD
Folsom Lake	American River	977	400[2]	USBR
Camanche Res.	Mokelumne River	417	200[1]	EBMUD
New Hogan Lake	Calaveras River	317	165	USACE
Farmington Dam	Littlejohns Creek	52	52	USACE
New Melones Lake	Stanislaus River	2,420	450	USBR
Don Pedro Reservoir	Tuolumne River	2,030	340	TID/MID
New Exchequer Dam (Lake McClure)	Merced River	1,025	350[1]	Merced ID
Buchanan Dam (Eastman Lake)	Chowchilla River	150	45	USACE
Hidden Dam (Hensley Lake)	Fresno River	90	65	USACE
Friant Dam (Millerton Lake)	San Joaquin River	521	170[1]	USBR
Pine Flat Lake	Kings River	1,000	475[1]	USACE
Terminus Dam (Lake Kaweah)	Kaweah River	143	136	USACE
Success Lake	Tule River	82	75	USACE
Isabella Lake	Kern River	568	400[1]	USACE

Notes: 1 -- Maximum flood control space may vary depending on upstream storage and/or snow pack
2 -- Does not include 270 taf reoperation for SAFCA

Project Owners:

USBR: U.S. Bureau of Reclamation	YCFCWCD: Yolo County Flood Control and Water Conservation District
DWR: California Department of Water Resources	EBMUD: East Bay Municipal Utility District
USACE: U.S. Army Corps of Engineers	TID: Turlock Irrigation District
YCWA: Yuba County Water Agency	MID: Modesto Irrigation District

USACE Operating Rules for Flood Control

USACE develops operating rules for all reservoirs providing flood control as a federally authorized purpose. These operating rules, as defined in each project's water control plan, are a compilation of regulating criteria, operating guidelines, guide curves, and specifications that govern the storage and release of water throughout the flood season. In California, coordination with project operators generally begins in the fall, prior to the flood season, when compliance with the water control plan is discussed. Factors that might cause operations to deviate from the water control plan are identified. These factors might include channel or levee conditions downstream, release limitations for fish and wildlife, construction activities, and other operational constraints. During the flood season, USACE may consult with the operating agency or local watermaster on project operation if deviations from the operating rules are noted. However, USACE's authority is limited to serving notice to the operating agency of any noncompliance to the water control plan. The ultimate responsibility for operation of the dam lies with the dam owner.

Flood control operations at Lake Oroville provide an illustration of USACE rules. Lake Oroville has a capacity of 3.5 maf and federally-purchased flood reservation of 0.75 maf. During the maximum flood reservation period of October 15 through March 31, detailed USACE operating criteria specify flood releases (during rainy periods) such that flows do not exceed channel capacity of 150,000 cfs from the dam downstream to Honcut Creek. Releases are also limited to not exceed 180,000 cfs above the mouth of the Yuba River, 300,000 cfs below the Yuba, and 320,000 cfs below the mouth of the Bear River.

Generally, flood control needs are greatest during the midwinter rainy season and diminish through the summer. Excessive inflows are temporarily stored in the flood control operating space while releases are held below the downstream channel capacity. After a storm, water within the flood pool is released gradually to prepare for the next possible storm. The actual storage requirement depends on how saturated the watershed is. However, the full amount of space is usually needed during a major storm event, so operators seldom encroach early in the flood season. The risk of having to spill excess water is too great; it is better to generate hydroelectric power with gradual releases if there are early season gains in storage, than to have a likely spill and potential damage downstream if a storm event occurs. Flood control storage requirements can be gradually eased during the spring to permit filling from snowmelt runoff.

Temperature Control Operations. Downstream water temperature has become an important criterion in establishing river and reservoir operations for the protection of salmon and other anadromous fish. For example, in 1990 and 1991 SWRCB established temperature standards in a portion of the Sacramento River through its Orders WR 90-5 and 91-01. These orders include a daily average water temperature objective of 56^0 F below Keswick Dam during critical periods when high temperatures could be detrimental to survival of eggs and pre-emergent fry. Through reservoir releases, the CVP attempts to maintain this temperature within the winter-run chinook salmon spawning grounds below Keswick Dam during April through September.

As another example of temperature control operations, NMFS issued a long-term winter-run chinook salmon biological opinion in 1993 that required the CVP to maintain a minimum Shasta Lake September storage of at least 1.9 maf, except in the driest years. Higher storage levels are required in Shasta Reservoir to ensure that cold water is available for reservoir releases. Before USBR constructed the temperature control device, water of sufficiently low temperature could be provided during critical periods only by bypassing Shasta Dam's power plant, causing an annual revenue loss to the CVP of $10 to $20 million. The TCD, constructed at a cost of about $83 million, has multi-level intakes, allowing temperature selective reservoir releases without having to bypass the power plant. Other dams, such as The Department's Oroville Dam, were constructed with the ability to make temperature-selective reservoir releases, as shown in the photo.

☞photo: Oroville intake structure

In certain cases, temperature control capability can be provided by a temperature control curtain. This technology has been used successfully to provide selective withdrawal and to control reservoir mixing at USBR's Lewiston and Whiskeytown reservoirs. The four curtains constructed at the two reservoirs have reduced temperature gains of Trinity River water by about 5^0 F. See Chapter 5 for more detailed discussion of temperature control technology.

Delta Operations. Because both the CVP and SWP export water from the Delta, a need for coordinated project operations exists. The Coordinated Operation Agreement between the Department and USBR classifies water in the Delta into two groups: storage withdrawals and surplus flows. Storage withdrawals belong to the project that makes the reservoir release. Surplus flows that are available for export are shared among the projects -- 55 percent to the CVP and 45 percent to the SWP. The COA also specifies how the projects are to share the responsibility of satisfying Sacramento River in-basin demands and Delta requirements when surplus flows are not available. Under such "balanced" conditions, responsibility is allocated 75 percent to the CVP and 25 percent to the SWP. The sharing of responsibility for satisfying new Delta requirements under Order WR 95-6 is not specified under the present COA.

Environmental needs in the Delta, especially for threatened and endangered fisheries, exert a strong influence on water project operation, particularly export pumping. Starting in the 1970s, project exports were reduced during May and June to improve juvenile striped bass survival in the Delta. In the last decade, requirements to protect ESA listed fish species have led to new Delta environmental criteria and more export constraints. Travel time to the Delta is a consideration in operating SWP and CVP reservoirs to meet regulatory requirements. Sometimes, a rapid change in salinity conditions calls for additional release of water. Of the major Sacramento River region reservoirs, Folsom gives the quickest response (about a day) while it takes 3 days for Oroville releases and 5 days for Shasta releases (or Trinity River water at Keswick Dam) to reach the Delta. Reservoir releases from New Melones reach the Delta through the San Joaquin River in about 1.5 days.

Stanislaus River releases from USBR's New Melones Reservoir must meet prior water rights and provide CVP water supply. Also, some water is dedicated to maintaining dissolved oxygen levels in the Stanislaus River and to diluting salts in the lower San Joaquin River. New Melones also must make spring pulse flow releases to meet Delta fishery requirements. Except during flood control operations, releases are maintained below 1,500 cfs to avoid seepage effects on adjacent orchard lands.

Impacts of Recent Events on Surface Water Supplies

As discussed in Chapter 2, several key events in California water have occurred since the last update of Bulletin 160. Events of particular importance to surface water supply availability include CVPIA implementation, the 1993 winter-run chinook salmon biological opinion, the Monterey Agreement, and the Bay-Delta Accord. The Department's DWRSIM computer model was used to evaluate the Bay-Delta Accord's impact on CVP and SWP operations under base year (1995) and future year (2020) conditions. A similar operations study, assuming D-1485 Delta standards and base year conditions, was conducted to compare delivery capability of the projects with the new Delta criteria. The 73-year simulations (1922-94) show how the CVP and

SWP would operate at current and future levels of demand and upstream development if the historic hydrology sequence were to repeat.

Based on these operations studies, Figures 3-25 and 3-26 show that delivery capabilities of the CVP (south of the Delta) and SWP were significantly reduced from the prior Delta operating criteria to the current criteria. Under D-1485 and 1995 level demands, the CVP had a 40 percent chance of making full deliveries and has a 95 percent chance of delivering 2.0 maf in any given year. Under WR 95-6 with identical demands, the CVP has a 20 percent chance of making full deliveries and has an 80 percent chance of delivering 2.0 maf in any given year. Under D-1485 and 1995 level demands, the SWP had a 70 percent chance of making full deliveries and a 95 percent chance of delivering 2.0 maf in any given year. Under WR 95-6 with identical demands, the SWP has a 65 percent chance of making full deliveries and an 85 percent chance of delivering 2.0 maf in any given year.

The operations studies also show significant impacts to the Delta export capability of the CVP and the SWP, especially in dry years. The combined 1995 level export of the CVP and SWP declined by about 300 taf per year on average and declined by about 850 taf per year during the 1928-34 drought. (Operation studies do not account for the Delta export curtailment resulting from take limits of listed species. The reduction in exports due to take limits could be significant, especially during drought periods, when the projects are unable to export significant unstored flows or reservoir releases providing required instream flows.) Table 3-13 summarizes key changes in Delta standards, as modeled in operations studies, from the Bulletin 160-93 base year to the Bulletin 160-98 base year.

Figure 3-25. 1995 Level CVP Delivery Capability South of the Delta Under D-1485 and WR 95-6

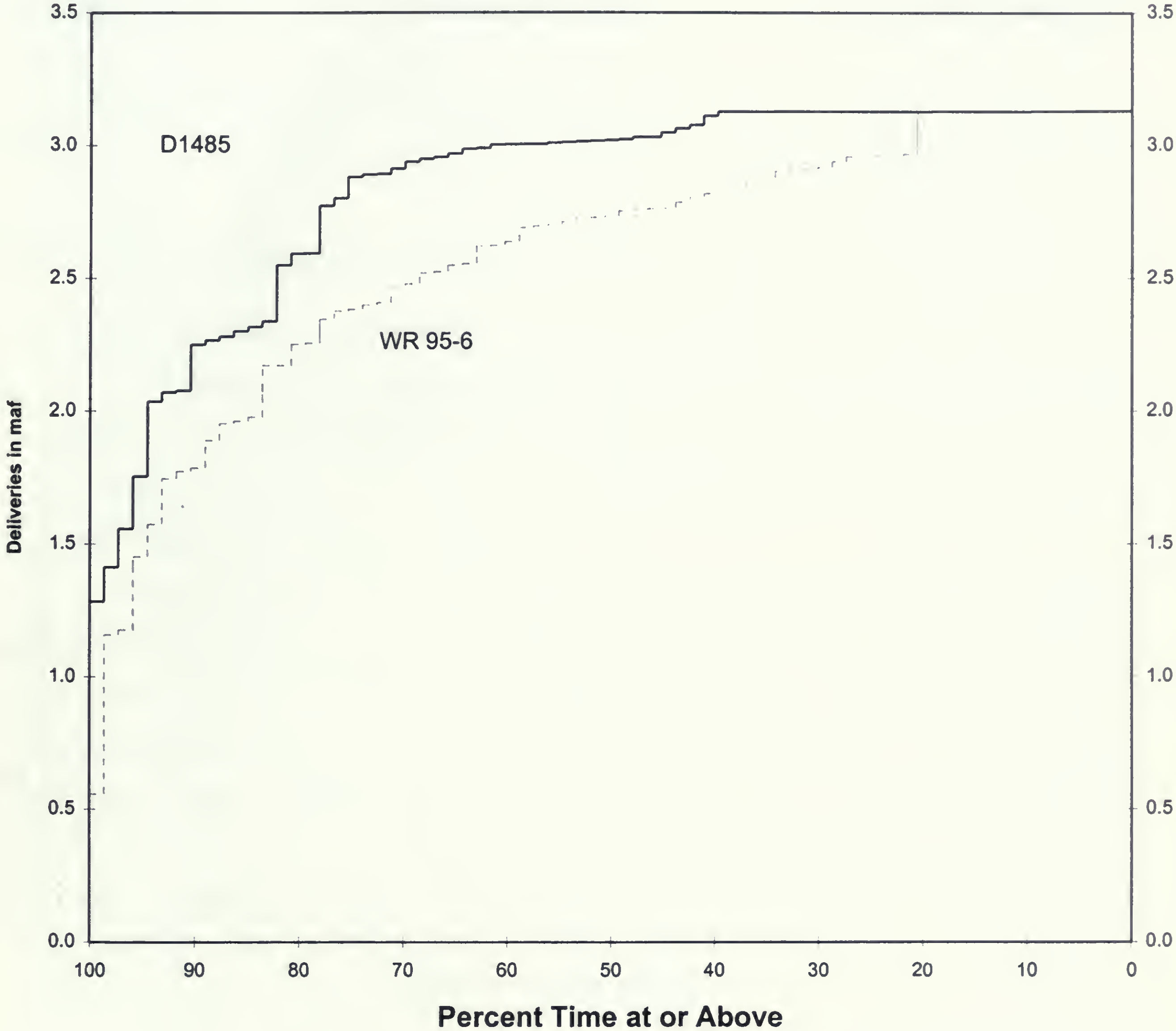

Figure 3-26. 1995 Level SWP Delivery Capability Under D-1485 and WR 95-6

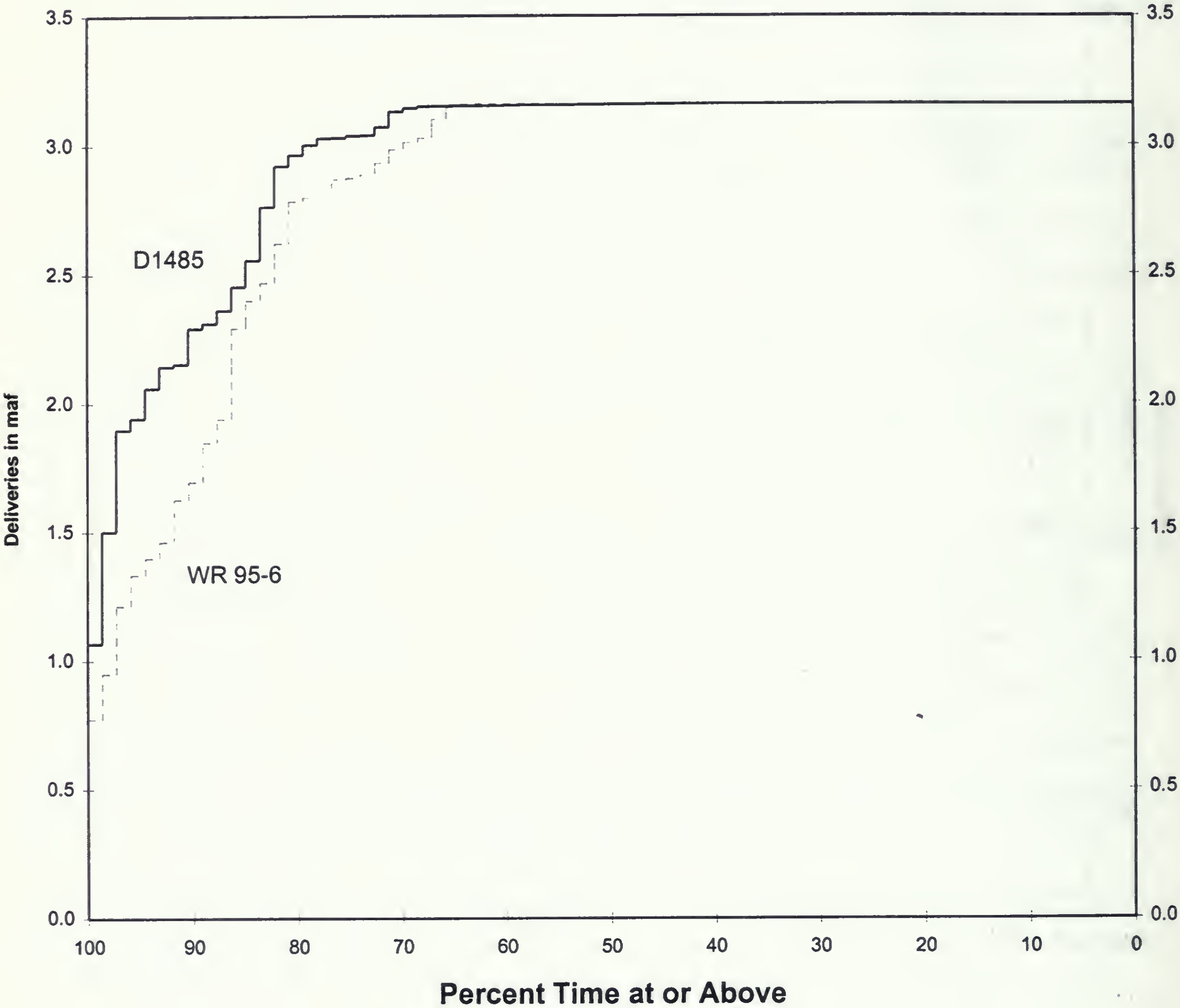

Table 3-13. Summary of Key Changes in Modeled Delta Standards B160-93 1990 Base Year (D-1485) to B160-98 1995 Base Year (WR 95-6)

Criteria	*Change*
Water Year Classification	from SRI to 40-30-30 Index
Sacramento River Flows	higher Sept.-Dec. Rio Vista flows
San Joaquin River Flows	new minimum and pulse flows
Vernalis Salinity Requirement	more restrictive during irrigation season, less restrictive other months
Delta Outflow	outflow required to maintain 2 ppt salinity during Feb.-June
Export Limits	35%-65% export-to-Delta inflow ratio, Apr.-May export-to-SJR inflow ratio
Delta Cross Channel Operations	additional closures required

Impacts of Reservoir Reoperation on Surface Water Supplies

California's large multipurpose reservoirs have been constructed to provide a certain mix of project benefits established during their planning periods. A change in a reservoir's operation rules (to increase one type of benefit) requires careful analysis of how the change may affect the project's ability to accomplish other purposes.

Providing additional winter flood control in a reservoir, for example, results in a higher probability of operators not being able to refill the reservoir after the flood season. Temporary increases in winter flood control space have been suggested at some of the San Joaquin River region foothill reservoirs in the wake of the 1997 flood. However, the value of water supply in this region is high, and these proposals would have significant costs and water supply impacts. At USBR's Folsom Reservoir, the local flood control agency has negotiated an agreement with USBR for an additional 270 taf of winter flood control space. The agreement requires the flood control agency to provide a substitute water supply, under specified conditions, if the flood control reservation results in a loss of supply to USBR.

Conversely, Chapters 7-9 discuss several flood control reservoirs being studied for reoperation to provide some water supply benefits. Many of these reservoirs are smaller, single-purpose flood detention impoundments on streams with relatively low average annual runoff. In many cases, physical changes to the existing dams, such as raising their spillways, would be needed as part of a reoperation for water supply. Often the goal at existing detention dams is to operate the reservoir to enhance groundwater recharge, because maintaining year-round conservation storage on a stream with relatively low average runoff would not be economical.

Providing higher reservoir carryover storage requirements, another example of reservoir reoperation, results in lower delivery potential during dry periods. The increase in required Shasta Reservoir storage to maintain cool water for the winter run salmon has reduced CVP water supply potential during dry periods. Current minimum storage target levels are about 1.9 maf, except in critical years when the target is allowed to drop to 1.2 maf. (Shasta storage dropped under 0.6 maf in the 1976-77 drought and dropped to 1.3 maf during the 1987-92 drought.)

Groundwater Supplies

In an average year, about 30 percent of California's urban and agricultural applied water use is provided by groundwater extraction. In drought years when surface supplies are reduced, groundwater can provide an even larger percentage of applied water. The amount of water stored in California's aquifers is far greater than that stored in the state's surface water reservoirs, although only a portion of California's groundwater resources can be economically and practically extracted for use.

In evaluating California water supplies, an important difference between surface water and groundwater must be accounted for -- the availability of data quantifying the resource. Surface water reservoirs are constructed to provide known storage capacities, reservoir inflows and releases can be measured, and stream gages provide direct measurements of flows in surface water systems. Groundwater basins have relatively indeterminate dimensions, inflow (e.g., recharge) to an entire basin cannot be directly measured, and total basin extractions and natural outflow can very seldom be directly measured. In addition to physical differences between surface water and groundwater systems, statutory differences in the administration of the resources also affect data availability. Entities who construct surface water reservoirs are required to have state water rights for the facility, and all but the smallest dams are regulated by the state's dam safety program. These requirements help define and quantify the resource. In contrast, groundwater may be managed by local agencies (as described later in this section), but there are no statewide requirements that require quantification of resource. Much of California's groundwater production is self-supplied, and is not managed or quantified by local agencies.

Readers will find that the following description of groundwater supplies is presented in a more general manner than was used for surface water supplies, reflecting the difference in data availability. Much of the groundwater information in this section is based on calculations, rather than on direct measurement. Estimating overdraft in a basin, for example, does rely on interpretation of measured data (water levels in wells), but also entails interpretation of calculated information (extractions from the basin).

Base Year Supplies

Table 3-14 provides estimated 1995 level groundwater supplies. The data include incidental reuse of water through deep percolation and exclude groundwater overdraft.

Table 3-14 Estimated 1995 Level Groundwater Supplies by Hydrologic Region (taf per year)

Hydrologic Region	*Average*	*Drought*
North Coast	263	294
San Francisco Bay	68	92
Central Coast	1,045	1,142
South Coast	1,177	1,371
Sacramento River	2,672	3,218
San Joaquin River	2,195	2,900
Tulare Lake	4,340	5,970
North Lahontan	157	187
South Lahontan	239	273
Colorado River	337	337
TOTAL	**12,493**	**15,784**

To help put this information in perspective, the following sidebar illustrates typical groundwater production conditions in three hydrologic regions that rely heavily on groundwater because their local surface water supplies do not support existing development. These regions -- the San Joaquin, Tulare Lake, and Central Coast regions -- all have alluvial aquifer systems that support significant groundwater development, as suggested by the information shown on well yields. (The data shown are typical of wells used for agricultural or municipal production. A well used to supply an individual residence would have a much smaller capacity. Over 90 percent of the ground water use in each of these regions is for agricultural use.) In contrast, aquifer systems in fractured rock, such as those used to supply small communities in the Sierra Nevada foothills, can generally support only limited groundwater development.

Groundwater Production Conditions

One of the Department's data programs is water level measurement in a statewide network of wells owned by local agencies and by individuals, to provide long-term information on changes in groundwater levels. Data from that program were combined with Bulletin 160 water use information to prepare the tables on typical groundwater production conditions shown below. (These data are intended to represent typical conditions. Individual areas within the basins listed may have conditions that deviate greatly from the typical conditions. In the Tulare Lake region, for example, groundwater production is occurring from wells with pump lifts of over 800 feet.) Long-term water level data can show the effects of increased groundwater extraction in drought years, and the effects of changing water management practices in a basin.

Within the San Joaquin River Region, approximately 2.6 maf of groundwater is extracted in a typical year. The following table shows typical characteristics associated with groundwater extraction in the San Joaquin River region, based on Department data, to illustrate how groundwater supply is developed in the region.

Typical Groundwater Production Conditions in the San Joaquin River Region

Basin	*Extraction (af/yr)*	*Well Yields (gpm)*	*Pumping Lifts (ft)*
Chowchilla	255,000	1500-1900	110
Delta Mendota	511,000	800-2000	35-150
Madera	565,000	750-2000	160
Merced	555,000	1500-1900	110
Modesto	229,000	1000-2000	90
Turlock	452,000	1000-2000	90
TOTAL	**2,567,000**		

In the Tulare Lake Region, approximately 5.6 maf of groundwater is pumped in a typical year. The following table shows typical characteristics associated with groundwater extraction in the Tulare region.

Typical Groundwater Production Conditions in Tulare Lake Region

Basin	*Extraction (af/yr)*	*Well Yields (gpm)*	*Pumping Lifts (ft)*
Kaweah	758,000	1000-2000	125-250
Kern	1,400,000	1200-1500	200-250
Kings	1,790,000	500-1500	150
Pleasant Valley	104,000	NA	350
Tulare Lake	672,000	300-1000	270
Tule	660,000	NA	300
Westside	213,000	800-1500	200-800
TOTAL	**5,597,000**		

In the Pajaro and Salinas Valley groundwater basins in the Central Coastal Region, approximately 0.61 maf of groundwater is pumped in a typical year. The following table shows typical characteristics associated with groundwater extraction in the Central Coast region.

Typical Production Conditions in Central Coastal Region

Basin	*Extraction (af)*	*Well Yields (gpm)*	*Pumping Lifts (ft)*
Pajaro Valley	64,000	500	10-300
Salinas Valley	550,000	1000-2000	70
TOTAL	**614,000**		

Groundwater Basin Yield

Historically, the term safe yield has been used in an attempt to describe the available supply from a groundwater basin. Safe yield is defined in the Department's Bulletin 118-80 (*Groundwater Basins in California*) as "the maximum quantity of water that can be continuously withdrawn from a groundwater basin without adverse effect." Adverse effect can include depletion of the groundwater reserves (groundwater level decline), intrusion of water of undesirable quality, impacts to existing water rights, higher extraction costs, subsidence, depletion of streamflow, and environmental impacts. Historically, additional extraction from a groundwater basin above the safe yield value has been called overdraft. Overdraft is defined in Bulletin 118-80 as "the condition of a groundwater basin where the amount of water withdrawn exceeds the amount of water replenishing the basin over a period of time."

Quantifying either overdraft or safe yield is inherently complex. For example, estimates of safe yield of a basin often change over time, as more development occurs in a basin and extractions increase. The observed effects of these extractions can cause water managers to revise - either upward or downward - safe yield estimates based on an earlier level of development. This update of the California Water Plan uses perennial yield rather than safe yield to define long-term groundwater basin yield.

Perennial Yield. Perennial yield is the amount of groundwater that can be extracted without lowering groundwater levels over the long-term. Perennial yield in basins where there is hydraulic connection between surface water and groundwater depends, in part, on the amount of extraction that occurs. Perennial yield can increase as extraction increases, as long as the annual amount of recharge equals or exceeds the amount of extraction. Extraction at a level that exceeds the perennial yield for a short period may not result in an overdraft condition. In basins with an adequate groundwater supply, increased extraction may establish a new hydrologic equilibrium with a new perennial yield. The establishment of a new and higher perennial yield requires that adequate recharge (from some surface supply) be induced. (Inducing recharge from surface supplies may impact downstream users of that supply.)

In Bulletin 160-98, perennial yield is estimated as the amount of groundwater extraction that has taken place, or could take place, over a long period of time under average hydrologic conditions without lowering groundwater levels. Existing basin water management programs (1995 level of development) were evaluated in the development of perennial yield estimates.

Overdraft. In this update of the California Water Plan, additional annual extraction from a groundwater basin over a long period of time above the annual perennial yield is defined as overdraft. In wet years, recharge into developed groundwater basins tends to exceed extractions from developed groundwater basins. Conversely, in dry years, groundwater basin recharge tends to be less than groundwater basin extraction. By definition, overdraft is not a measure of these annual fluctuations in groundwater storage volume. Instead, overdraft is a measure of the long-term trend associated with these annual fluctuations. The period of record used to evaluate overdraft must be long enough to produce data that, when averaged, approximates the long-term average hydrologic conditions for the basin. Table 3-15 shows The Department's estimate of 1995-level groundwater overdraft by hydrologic region.

Table 3-15. Estimated Overdraft by Hydrologic Region

Hydrologic Region	*Overdraft (taf/yr)*
North Coast	0
San Francisco Bay	0
Central Coast	210
South Coast	0
Sacramento River	30
San Joaquin	240
Tulare Lake	820
North Lahontan	0
South Lahontan	90
Colorado River	70
TOTAL	**1,460**

Water supply shortages associated with SWRCB's Order WR 95-6, ESA requirements, and CVPIA implementation have had short-term impacts on groundwater levels in the San Joaquin and Tulare Lake regions. CVP contractors in these regions who rely on Delta exports for their surface water supply have experienced supply deficiencies of up to 50 percent subsequent to implementation of export limitations and CVPIA requirements, and have turned to groundwater pumping for additional water supplies. This increase in groundwater use exacerbated a short-term decline in water levels as a result of the 1987-1992 drought. Long-term cutbacks in surface water supplies south of the Delta will also translate into long-term increases in groundwater extractions south of the Delta. Bulletin 160-98 estimates a statewide increase in groundwater overdraft (160 taf/yr) above the 1990 base year reported in the previous California Water Plan update. Most of the statewide increase in overdraft is expected to occur in the San Joaquin and Tulare Lake regions, two regions where surface water supplies were reduced by Delta export restrictions and CVPIA requirements.

Groundwater quality degradation is another factor that should be considered when computing overdraft. Groundwater overdraft in a basin may cause the movement of poor quality water into higher quality water. The resulting quality degradation may reduce the usable storage in a groundwater basin. This adverse effect was evaluated and included in the updated overdraft computations.

The Central Coast hydrologic region includes several small basins with limited storage capacity. During drought periods, water levels in these basins may decline to a point where groundwater is not usable. However, during wet periods, most of these basins recover, thus making application of overdraft or perennial yield concepts difficult. The Department is currently evaluating Central Coast region groundwater use to better estimate overdraft, but this evaluation will not be completed in time for Bulletin 160-98. Parts of the Central Coast have received CVP water through the San Felipe Tunnel since 1986; other parts will soon receive SWP water through the Coastal Branch of the California Aqueduct. These imported supplies should help reduce overdraft in the region.

Seawater Intrusion in Orange County

The Orange County Water District was formed in 1933 to protect and manage the groundwater basin that underlies the northwest half of the county, which supplies about 75 percent of OCWD's total water demand. As the county developed, increased groundwater demands resulted in a gradual lowering of the water table. By 1956, years of heavy pumping to sustain the region's agricultural economy had lowered the water table below sea level, and saltwater from the ocean had encroached as far as five miles inland. The area of seawater intrusion is primarily along 4 miles of coast between Newport Beach and Huntington Beach know as the Talbert Gap.

To prevent further seawater intrusion, OCWD operates a hydraulic barrier. A series of 23 multi-point injection wells 4 miles inland delivers fresh water into the underground aquifer to form a water mound, blocking further passage of seawater. Water supply for the Talbert Barrier is produced at OCWD's Water Factory 21. The supply is a blend of 62 percent recycled water and 38 percent groundwater pumped from a deep aquifer zone that is not subject to seawater intrusion. The first blended recycled water from the plant was injected into the barrier in October 1976.

Water Factory 21 recycles about 15 mgd, and with the deep well water used for blending, produces about 22.6 mgd. OCWD has applied for and has received a permit to modify the treatment process to allow for injection of 100 percent recycled water, eliminating the use of deep well water for blending. The plant's current treatment includes chemical clarification, recarbonation, multi-media filtration, granular activated carbon, reverse osmosis, chlorination, and blending. The blended injection water has a total dissolved solids content of 500 mg/L or lower, and meets DHS primary and secondary drinking water standards.

Land Subsidence

Land subsidence caused by groundwater withdrawal has occurred in parts of the Central and Santa Clara valleys, and in localized areas of the south coastal plain. An important groundwater management goal is the prevention or reduction of land subsidence. Land subsidence can impact infrastructure, roads, buildings, wells, canals and stream channels, flood control structures (such as levees), and low-lying coastal or floodplain areas. Actions to manage subsidence may include: (1) monitoring changes in groundwater levels, (2) precisely surveying land surface elevations at periodic intervals to detect changes, (3) installing extensometers to measure the change in thickness of sediments between the land surface and fixed points below the surface, (4) recording the amount of groundwater extracted, (5) recharging the aquifer to control subsidence, and (6) determining when extraction must be decreased or stopped.

One area where subsidence has been of particular concern is the west side of the San Joaquin Valley, where infrastructure affected by subsidence includes state highways, county roads, and water conveyance and distribution facilities. The accompanying sidebar provides an overview of subsidence in the area.

Land Subsidence in the San Joaquin Valley

San Joaquin Valley land subsidence was observed as early as the 1920s. The rate of subsidence increased significantly in the post-WWII era as groundwater extraction increased. Subsidence was especially noticeable along parts of the west side of the valley, where land that had been used for grazing or dry farming was converted to irrigated agriculture. By 1970, 5,200 square miles in the valley had subsided more than 1 foot. Between 1920 and 1970, a maximum of 28 feet of subsidence was measured at one location southwest of Mendota. In the years since 1970, the rate of subsidence has declined because surface water was imported to the area. An increase in subsidence occurred during the 1976-77 and 1987-92 droughts, when groundwater extraction increased due to reductions in SWP and CVP supplies. Recent increases in subsidence are the result of increased groundwater extractions to compensate for water supply deficiencies caused by Bay-Delta export restrictions, ESA requirements, and CVPIA.

The Department monitors subsidence along the California Aqueduct, maintaining seven compaction recorders and performing periodic precise leveling along the Aqueduct. The data indicate, for example, that a 68-mile reach of the aqueduct near Mendota subsided 2 feet between 1970 and 1994. In the south end of the San Joaquin valley over the same time period, the Aqueduct subsided approximately 2 feet along a 29-mile reach near Lost Hills, and up to 1 foot in a 9-mile reach near the Kern Lake Bed. At the time of the Aqueduct's design, the potential for San Joaquin Valley subsidence was recognized, and measures were taken to compensate for some of its impacts. Canal sections in subsidence-prone areas were designed with extra freeboard, and structures crossing the canal (such as bridges) were designed to allow them to be raised later. Even so, continued subsidence along the Aqueduct alignment creates the need for costly repairs and reduces the canal's capacity in places.

Groundwater Management Programs

Because no two groundwater basins are identical, local agency groundwater basin management programs differ in purpose and scope. Typical local groundwater management strategies include monitoring groundwater levels and well extractions; cooperative arrangements among pumpers to minimize or eliminate problem conditions; and, where applicable, conjunctive use. Groundwater management options include AB 3030 plans (Water Code Section 10750, *et seq.*), local ordinances, and legislative authorization for individual special districts. Rights to use groundwater also may be adjudicated by court action. Table 2A-1 in the Appendix 2A lists agencies that have adopted AB 3030 plans as of January 1997. A map of groundwater management districts and agencies with AB 3030 plans appears in Figure 3-27.

Basin Adjudication. In California's adjudicated groundwater basins, groundwater extraction is regulated or administered by a court-appointed watermaster. The court retains jurisdiction over the judgment, so parties can appeal to the court to resolve disputes related to their adjudicated rights. The groundwater that each well owner can extract is determined by the court decision as administered by the watermaster. While each court decision may be different, the goal is to avoid groundwater overdraft by providing sustainable supply. Table 3-16 shows a list of adjudicated basins.

Table 3-16. California Adjudicated Groundwater Basins and Watermasters

County	*Basin*	*Watermaster*
Los Angeles	Central	DWR
	West Coast	DWR
	Upper Los Angeles River Area	An individual specified in the court decision
	Raymond	Raymond Basin Management Board
	Main San Gabriel [1]	Nine-director board
	Main San Gabriel - Puente Basin [2]	Two individuals
Kern	Cummings	Tehachapi-Cummings Water District
	Tehachapi	Tehachapi-Cummings Water District
San Bernardino	Warren Valley	Hi-Desert Water District
	San Bernardino Basin Area	One representative each from Western Municipal Water District of Riverside County and San Bernardino Valley Municipal Water District
	Cucamonga	Not yet appointed
	Mojave River	Mojave Water Agency
Riverside and San Bernardino	Chino	Chino Basin Municipal Water District
Siskiyou	Scott River Stream System	Scott Valley Irrigation District

1 The watermaster for Main San Gabriel Basin in Southern California has returned to court and obtained approval of regulations to control extraction for protecting groundwater quality.

2 Groundwater underflow from Puente Basin, a part of Main San Gabriel Basin, was addressed in a court decision separate from the Main San Gabriel adjudication. The court named two individuals to act as watermaster.

Figure 3-27. Locations of Groundwater Management Districts and Agencies with Groundwater Management Plans

Groundwater and surface water have also been adjudicated in the Santa Margarita River Watershed in Riverside and San Diego counties (not listed in Table 3-16). Water users are required by the court decision to report to the court-appointed watermaster the amount of groundwater they extract from the aquifer and the amount of surface water they divert from the river, canals, or ditches. However, groundwater extraction is not limited by the decision.

Special Powers Agencies and Local Ordinances. The California Legislature may create special powers agencies, such as the Fox Canyon Groundwater Management District, or may amend the statutory authority of an existing agency to allow it to manage groundwater. Generally, these agencies are governed by a board of directors that may be appointed or elected.

The *Baldwin v. County of Tehama* decision confirmed the right of cities and counties to adopt local regulations concerning groundwater. Moreover, the *Baldwin* decision confirmed that Tehama County has general police power to regulate groundwater and water transfers, and that counties are free to adopt local ordinances that do not conflict with state legislative mandates. The following counties have ordinances regulating groundwater: Butte, Glenn, Imperial, San Benito, San Joaquin, Tuolumne, and Tehama.

Water Transfers, Exchanges, and Banking

During recent years, water transfers, exchanges, and banking have received increasing attention as a means of overcoming water supply/demand imbalances. Experiences with temporary transfers during and since the 1987-92 drought bolstered interest in transfers as a water management tool. In this update of the California Water Plan, water transfers are defined as:

- the permanent sale of a water right by the water right holder:
- a lease from the water right holder, who retains the water right, but allows the leasee to use the water under specified conditions over a specified time-period; or
- the sale or lease of a contractual right to water supply. The ability of the holder of a contractual right to water supply to transfer the contractual right usually requires the approval of the agency supplying the water. An example of this type of transfer would be a transfer proposed by a water agency that received its supply from the CVP, SWP, or other water wholesaler.

Water exchanges between individual water users within a water district are common in dry years, and such transfers are becoming increasingly common even in average years. Water exchanges between users within a district normally do not require approval from the SWRCB because there is no change in the type, place, or time of use. Water exchanges of this type are not considered transfers for the purposes of Bulletin 160.

Water banking -- where water is physically banked or stored without a change in ownership of the water -- is not considered a water transfer in this Bulletin. For example, Warren Act contracts, where local agencies contract with USBR for storage or conveyance of non-project water in federal facilities, only involve the rental of facilities for storage or conveyance. Water banking agreements where ownership of the water does change hands are considered water transfer agreements in this Bulletin. For example, the MWDSC-Semitropic Water Storage District agreement allows MWDSC access to 35 percent of Semitropic's groundwater storage capacity. MWDSC may store a portion of its SWP entitlement water for later withdrawal and delivery to its service area. However, Semitropic WSD could exchange a portion of its SWP entitlement water for MWDSC's stored water, thereby making this banking arrangement a water transfer.

Short-Term Agreements

Short-term agreements have made up the majority of water marketing arrangements in recent years. Short-term transfers, executed for one year or less, can be an expedient means of alleviating the most severe drought year impacts. Short-term transfers can be made on the spot market; however, water purveyors are increasingly negotiating long-term agreements for drought year transfers. In such agreements, specific water supply conditions are used to determine whether water would be transferred in a specific year.

Two examples of programs for acquiring water through short-term agreements are the Drought Water Bank and the CVPIA interim water acquisition program. These programs are discussed below. Beyond these programs, data on short-term water transfers are difficult to locate and verify (transfers executed for less than one year do not need SWRCB approval and thus are not tracked by outside entities) and are difficult to evaluate (data often do not distinguish between exchanges and transfers).

Drought Water Bank. In 1991, after four years of drought, the Governor signed an executive order establishing a Drought Action Team. The first emergency drought water bank was created in response to the team's recommendations. The Department operated the DWB. DWB's primary role was to purchase water from willing sellers and sell it to entities with critical needs. Sellers made water available to DWB by fallowing farmland and transferring the conserved irrigation water to DWB, using groundwater instead of surface water, or transferring water stored in local reservoirs.

During 1991, the DWB purchased about 820,000 af of water under more than 100 short-term agreements. About 51 percent of that water came from agreements to not irrigate farmland during part of the year. About 31 percent came from various groundwater exchange agreements made with participating farmers and water districts. The rest of the water came from stored water reserves.

The 1991 DWB experience and contracts provided a basis for administration of the 1992 DWB. Unlike the 1991 DWB, water for the 1992 DWB was purchased only to meet prior contractual commitments. The 1992 DWB included 19 sellers and 16 buyers. Water was purchased primarily through reservoir storage release and groundwater substitution contracts. No land fallowing contracts were executed. These conditions allowed the 1992 DWB to operate at a significantly reduced cost for water. The DWB was able to acquire sufficient water to meet the critical needs of all participants.

Drawing on the 1991 and 1992 DWB experiences, the Department completed a programmatic environmental impact report that evaluated different categories of transfers. The final EIR released in 1993 covered a drought water bank program intended to meet water demands during periods of drought and other severe water-short periods over the next 5 to 10 years, on an as-needed basis. The program is a water purchasing and allocation program whereby the Department will purchase water from willing sellers and market the water to buyers under specific critical needs allocation guidelines.

The DWB program would be implemented as needed for a particular year by an executive order of the Governor or upon a finding by the Department's Director that drought or other unanticipated conditions exist that would significantly curtail water deliveries. The program would continue to operate until water supplies returned to noncritical levels.

In 1994, the Department reactivated the DWB and also initiated a short-term water purchase program for SWP contractors. More than 173,000 af of water was delivered to cities and farms throughout the State. About 115,000 af was delivered from the DWB and 58,000 af was delivered from the short-term water purchase program. A comparison of the three DWBs is shown in Table 3-17.

Table 3-17. California Drought Water Banks' Purchases (af)

	1991 Bank	1992 Bank	1994 Bank[1]
Purchases	820,664	193,246	221,754
Delta & instream fish requirements	-165,137	-34,478	-48,271
Net Supply	655,527	158,768	173,483
Allocations (af)			
Urban Uses	307,373	39,000	23,840
Agricultural Uses	82,597	95,250	149,643
Environmental Uses	---------	24,518	---------
SWP[2]	265,558	---------	---------
Total Allocations	655,528	158,768	173,483
Unit Price to Buyer ($/af)[3]			
	175	72	68

1 Includes deliveries for the SWP.
2 Carryover water for the SWP.
3 Price to buyers south of Sacramento - San Joaquin Delta at Banks Pumping Plant. Includes the cost of the water, adjustments for carriage losses and administrative charges. Does not include transportation charges which have ranged from $15 to $200 per acre-foot, depending on the point of delivery and other factors.

The Department began to organize a 1995 DWB in September 1994, anticipating another dry year. By mid-November, water agencies had signed contracts with the Department to purchase water from DWB for critical needs, and the Department had established DWB in an inactive status, with the intent of activating it if 1995 precipitation was below normal. While in inactive status, DWB purchased options on 29 taf of water from five willing sellers. As a result of an abundance of precipitation and snowpack throughout California in 1995, the DWB was not activated and the Department did not exercise the acquired options.

Despite the success of the DWB, it is a contingency or drought management supply option. It is not a permanent water supply. Based upon past experience, future State-operated DWBs might be able to reallocate about 250 taf/yr of supplies during droughts. However, the ability to purchase dry year supplies for future DWBs will become increasingly difficult as water shortages increase.

CVP Interim Water Acquisition Program. Short-term water transfers have provided supplies to meet fish and wildlife water requirements of the CVPIA. An interim water acquisition program was established to acquire water while long-term planning for supplemental fishery water acquisition and refuge water supply acquisition continues. The program, a joint effort by USBR and USFWS, is to be in place from October 1995 through February 1998. A 1995 Final Environmental Assessment and Finding of No Significant Impact for the program addressed the regional impacts associated with four categories of water acquisition. The four categories were:

- acquisition of up to 13,123 af/yr of water for wildlife refuges in the Sacramento Valley;
- acquisition of up to 45 cfs of water flows on Battle Creek for spawning and migration of winter and spring run chinook salmon and steelhead trout;
- acquisition of up to 52,421 af/yr of water for wildlife refuges within the San Joaquin Valley; and
- acquisition of up to 100,000 af/yr of water on each of the Stanislaus, Tuolumne, and Merced rivers to meet instream flows for anadromous fish and to help meet Bay-Delta flow and water quality requirements on the San Joaquin River.

Table 3-18 summarizes purchases made under the program in 1995 and 1996. In the program's second phase, USBR and USFWS completed a Supplemental Environmental Assessment and entered into agreements with PG&E for reduced diversions on Battle Creek in 1996 and 1997 and with Merced Irrigation District to purchase up to 100,000 af of water in 1997 to improve flows on the Merced River.

Table 3-18. CVP Interim Water Acquisition Program (af/yr)

	1995	1996
Level 4 Water Acquisition		
San Joaquin River Exchange Contractors	25,000	30,318
Semitropic Water Storage District	5,200	6,802
Subtotal	**30,200**	**37,120**
Supplemental Water Acquisition		
Merced Irrigation District	--	120,000
TOTAL	**30,200**	**157,120**

Long-Term Agreements

Table 3-19 presents several long-term agreements completed in recent years. Long-term agreements currently being negotiated are presented as future water management options and are discussed in Chapter 6.

Table 3-19. Recently Completed Long-Term Water Transfer Agreements

From	*Region*	*To*	*Region*	*Amount (taf/yr)*
Westside Water District[1]	Sacramento River	Colusa County Water District	Sacramento River	25
Kern County Water Agency[1]	Tulare Lake	Alameda County Flood Control and Water Conservation District, Zone 7	San Francisco	7
Kern County Water Agency[1]	Tulare Lake	Mojave Water Agency	Colorado River	25
Semitropic Water Storage District	Tulare Lake	Santa Clara Valley Water District	San Francisco	32 - 78
Semitropic Water Storage District	Tulare Lake	Metropolitan Water District of South California	South Coast	32 - 78
Imperial Irrigation District	Colorado River	Metropolitan Water District of South California	South Coast	106 maximum

[1] This is a permanent transfer of contractual entitlement. The amount shown is the contractual entitlement and may not reflect actual deliveries.

One of the terms in the SWP's Monterey Agreement was that agricultural contractors would make 130,000 af of SWP annual entitlement available for permanent transfer to urban contractors (on a willing buyer-willing seller basis). In 1997, Kern County Water Agency concluded the transfer of 25,000 af to Mojave Water Agency. KCWA is also in the process of permanently transferring up to 7,000 af of entitlement to Alameda County Flood Control and Water Conservation District, Zone 7. As with the SWP, entitlement transfers among CVP contractors are now taking place. In 1997, USBR completed an environmental assessment for a proposed long-term transfer of 25,000 af of water from the Westside Water District to the Colusa County Water District.

Banking project water outside of an SWP contractor's service area for later use within its service area is also provided for in the Monterey Agreement. SWSD has developed a groundwater storage program with 1 maf of storage capacity. Under this program, an SWP contractor may negotiate an agreement with SWSD to deliver SWP water to SWSD for in-lieu groundwater recharge. At the contractor's request, groundwater would be extracted and delivered to the California Aqueduct, or otherwise exchanged for entitlement. Currently, MWDSC and SCVWD have long-term agreements with SWSD for 350,000 af of storage. Alameda County Water District is in the process of signing a similar agreement for 50,000 af of storage.

In addition to the MWDSC-IID transfer shown in Table 3-19 (described in Chapter 9), MWDSC has executed an agreement for groundwater banking in Arizona. Under an existing agreement between MWDSC and the Central Arizona Water Conservation District, MWDSC can store a limited amount of unused Colorado River water in Arizona for future use. The Southern Nevada Water Authority is also participating in the program. The agreement stipulates that MWDSC and SNWA can store up to 300 taf in central Arizona through the year 2000. To date, MWDSC has placed 89 taf of water in storage and SNWA has placed 50 taf of water in storage for a total of 139 taf. About 90 percent of the stored water can be recovered, contingent upon the declaration of surplus conditions on the Colorado River. When MWDSC is able to draw on this source, it can divert up to a maximum of 15 taf in any one month. The stored water would be made available to MWDSC by Arizona foregoing the use of part of its normal supply from the Central Arizona Project. MWDSC plans to recover the stored water at times in the future when its Colorado River Aqueduct diversions may be limited.

Water Recycling and Desalting Supplies

Water recycling is the intentional treatment and management of wastewater to produce water suitable for reuse. Several factors affect the amount of wastewater treatment plant effluent that local agencies are able to recycle, including the size of the available market and the seasonality of demands. Local agencies must plan their facilities based on the amount of treatment plant effluent available and the range of expected service area demands. In areas where landscaping uses constitute the majority of recycled water demands, there can be a great variation between winter and summer demands. (Where recycled water is used for groundwater recharge, seasonal demands are more constant throughout the year.) Also, since water recycling projects are often planned to supply certain types of customers, the proximity of these customers to each other and to available pipeline distribution systems affects the economic viability of potential recycling projects.

Technology available today allows municipal wastewater treatment systems to produce water supplies at competitive costs. More stringent treatment requirements for disposal of municipal and industrial wastewater have reduced the incremental cost higher levels of treatment required for recycled water. The degree of additional treatment depends on the intended use. Recycled water is used for agricultural and landscape irrigation, groundwater recharge, and industrial and environmental uses. Some uses are required to meet more stringent standards for public health protection. Examples include a project to provide recycled water to irrigate 10,000 acres of vegetables, including vegetables such as salad greens (which are normally eaten without having been cooked) in the northern Salinas Valley. Another example is the City of San Diego's planned 20 mgd treatment plant to produce repurified water. This water project (described in Chapter 5) would produce about 15,000 af per year of repurified water to augment local municipal supplies, and if implemented, would be California's first indirect potable reuse project.

The use of recycled water can lessen the demand for new water supply. However, not all water recycling produces new water supply. Bulletin 160 counts water that would otherwise be lost to the State's hydrologic system (e.g., water discharged directly to the ocean) as recycled water supply. If water recycling creates a new demand which would not otherwise exist or if it recycles water that would have been otherwise been used by downstream entities or recharged to usable groundwater, it is not considered new water supply.

Water Recycling Status

The Department, in partnership with the WateReuse Association of California, conducted a 1995 survey to update the Association's 1993 survey. The purpose of the surveys was to determine local agencies' plans for future water reuse. The 1993 survey was used in Bulletin 160-93 to estimate recycling potential. Bulletin 160-98 uses data from the 1995 survey.

The 1993 survey, with 111 respondents, reported total annual water recycling of 384,000 af. The 1995 survey, with 230 respondents reported total recycling of 485,000 af per year, with 323,000 af/year being new water supply. One hundred ninety-one new water reuse projects have been constructed since 1993. As shown in Table 3-20, which presents current water recycling by hydrologic region, recycling projects do not generate new water supply in the State's interior regions, because the water constituting their source of supply would otherwise be used by downstream entities or would be recharged to groundwater.

Table 3-20. Base Year (1995) Reuse by Hydrologic Region

Region	*Reuse (taf/yr)*	*Percent of Total (%)*	*New Water Supply (taf/yr)*
North Coast	13	3	13
San Francisco Bay	40	8	35
Central Coast	19	4	18
South Coast	263	54	207
Sacramento River	12	2	0
San Joaquin River	37	8	0
Tulare Lake	51	11	0
North Lahontan	8	2	8
South Lahontan	27	5	27
Colorado River	15	3	15
Total	**485**	**100**	**323**

The 1993 survey respondents reported plans to recycle more than 650,000 af/yr of water by 1995. This level of recycling did not materialize. The most obvious reason for the shortfall between 1993 projections for 1995 and the actual 1995 recycling was because the 1993 survey was administered when the memory of the 1987-92 drought was vivid. When asked about factors that influence water recycling decisions, respondents reported that "memory of the last drought" and "concern over long-term supply" were most likely to influence recycling decisions. Financial problems and recession were identified as least likely to affect recycling decisions. Existing use of recycled water is shown in Table 3-21. Examples of types of reuse in the "Other" category include snow making, dust suppression, fire fighting, and recreational ponds.

Table 3-21. Base Year (1995) Use of Total Recycled Water by Category

Type of Reuse	Amount (taf per year)	Percent of Total
Agricultural Irrigation	155	32
Groundwater Recharge	131	27
Landscape Irrigation	82	17
Industrial Uses	34	7
Environmental Uses	15	3
Seawater Intrusion Barrier	5	1
Other	63	13
TOTAL	**485**	**100**

Water Recycling Potential

By 2020, total water recycling potential is expected to increase from 485 taf/yr to 615 taf/yr due to greater production at existing treatment plants and new production at plants currently under construction. This base production is expected to increase new recycled supplies from 323 taf/yr to 468 taf/yr. All new recycled water is expected to be produced in the San Francisco Bay, Central Coast, and South Coast regions. Table 3-22 shows projections of future water recycling and resulting new water supply based on the 1995 survey. Future potential water recycling includes projects now in the planning stage, as well as conceptual projects which have not yet begun planning for facility construction.

☞photo: local agency plant in coastal area

Table 3-22. Projections of Future Water Recycling and Resulting New Water Supply (taf per year)

	1995		2020	
Projects	Total Water Recycling	New Water Supply	Total Water Recycling	Total Water Supply
Base	485	323	615	468
Planned	-----	-----	837	699
Conceptual	-----	-----	131	31
TOTAL	**485**	**323**	**1,583**	**1,198**

By 2020, water recycling projects that are in the planning and conceptual stages are expected to bring total water recycling potential to nearly 1,600 taf/yr, or about 1,200 taf per year of new supply. (In addition, the 1995 survey also tabulated survey respondents' view of water recycling potential beyond the 2020 planning horizon of Bulletin 160-98. Beyond 2020, the survey reported an additional 0.2 maf/yr of wastewater statewide, potentially generating an additional 0.1 maf/yr of new water supply.)

Future water recycling options are discussed in Chapter 6 and in the regional chapters.

Water Quality

A critical factor in determining the usability and reliability of any particular water source is water quality. The quality of a water source will significantly affect the beneficial uses of that water. Water has many potential uses, and the water quality requirements for each use vary. Sometimes, different water uses may have conflicting water quality requirements. For example, water temperatures desirable for irrigation of some crops may not be suitable for fish spawning.

Overview of Pollutants and Stressors Causing Water Quality Impairment

Mineralization. When water passes over and through soils, it picks up soluble minerals (salts) that are the result of natural processes, such as geologic weathering. As the water passes through a watershed and is used for various purposes, concentrations of dissolved minerals and salts in the water increase, a process called mineralization. For example, when Sierra Nevada streams flow into the valley floors, they typically pick up 20 to 50 milligrams per liter of dissolved minerals, which is equivalent to about 50 to 140 pounds of salts per acre-foot. An acre-foot of water with total dissolved solids of 736 mg/L contains one ton of salt, a concentration typical of water in the lower Colorado River. Increased concentrations of minerals can result from both urban and agricultural water uses, as illustrated in the section on pollutants in agricultural and urban runoff.

In the Sacramento-San Joaquin Delta, the export location for much of California's water supply, sea water intrusion is a major source of mineralization. Sea water intrusion in the Delta elevates the salinity (particularly the concentrations of ions of concern: sodium, chloride, and bromide) of fresher river water entering the Delta. The impact of sea water intrusion is especially significant during periods of low river flows. For example, during the drought from 1987 to 1992, the average concentration of dissolved solids (salt) in the lower Sacramento River was 108 mg/L. In the lower San Joaquin River, the average was 519 mg/L, and at Banks Pumping Plant, the southern Delta export location of the SWP, the average was 310 mg/L. During the wetter years from 1993 to 1995, the average concentration of dissolved solids in the lower Sacramento River was 98 mg/L, while the average concentration of dissolved solids was 342 mg/L in the lower San Joaquin River and 236 mg/L at Banks Pumping Plant. Bromides contributed by sea water intrusion are of particular concern because they contribute to the formation of disinfection by-products when the water is treated for drinking.

Eutrophication. Eutrophication results when nutrients such as nitrogen and phosphorus are added to surface waters. In the presence of sunlight, algae and other microscopic organisms use the available nutrients to increase their populations. Slightly or moderately eutrophic water can be healthful and can support a complex web of plant and animal life. However, water containing high concentrations of microorganisms is undesirable for drinking water and other needs. Some microorganisms can produce compounds that, while not directly harmful to human health, may cause taste and odor problems in drinking water.

Nowhere is the subject of eutrophication of greater concern than at Lake Tahoe, where stringent regulatory controls have been imposed to maintain, or at least halt the decline of the lake's unique clarity. The lake is in the early stages of eutrophication and, if it continues, its clarity will be significantly reduced in 20 to 40 years. About one and a half feet of transparency have been lost each year since the early 1960s. Development of the basin's erodible land, as well as construction of highways, streets, and logging roads, generates phosphorous and nitrogen compounds that are deposited in Lake Tahoe, spurring algae growth. Algae and suspended sediments cloud the lake and reduce its transparency. The combination of the lake's large volume and the fact that it has only one outlet, the Truckee River, aggravates the impacts of the phosphorous and nitrogen loading because there is virtually no flushing action.

Abandoned Mines. Runoff from abandoned mines contributes to loading of metals such as nickel, silver, chromium, lead, copper, zinc, cadmium, mercury, and arsenic in surface waters. Iron Mountain Mine on Spring Creek above Keswick Reservoir and Penn Mine above Comanche Reservoir are examples of abandoned mines that drain into major watersheds. Periodic fish kills have been experienced at these sites as a result of elevated levels of metals in mine drainage flows. Concentrations of metals well below levels of concern for humans can be acutely toxic to many aquatic species. Much of the heavy metal loading in the Sacramento River is thought to come from abandoned mines in the upper watershed.

Pathogens. *Cryptosporidium parvum* outbreaks have been documented in many places throughout the world. Table 3-23 lists some of the most significant outbreaks documented in recent years. In April 1993, approximately 403,000 persons in Milwaukee, Wisconsin became ill of cryptosporidiosis, the disease caused by *Cryptosporidium* in their water supply. Approximately 100 deaths resulted from this outbreak. The suspected sources of *Cryptosporidium* were cattle wastes, slaughterhouse wastes, and sewage carried by rivers tributary to Lake Michigan, the water body used as the source of drinking water. This outbreak was associated with operational deficiencies in the water treatment plant, and presents a compelling example of the importance of maintaining the quality of source waters.

Table 3-23. Significant *Cryptosporidium* Outbreaks

Year	*Location*	*Approximate Number of Reported Cases*
1984	Braun Station, Texas	2,000 cases
1987	Carrollton, Georgia	13,000 cases
1989	Thames River area, England	100,000 cases
1992	Jackson County, Oregon	15,000 cases
1993	Milwaukee, Wisconsin	403,000 cases, 100 deaths
1994	Las Vegas, Nevada	78 cases, 16 deaths

More significantly, the 1994 *Cryptosporidium* outbreak in Las Vegas, Nevada was the first documented epidemiologically-confirmed waterborne outbreak from a water system with no associated treatment deficiencies or breakdowns. During this outbreak, 78 immunocompromised persons became ill of cryptosporidiosis, even when no *Cryptosporidium* was detected in the treated drinking water.

Federal and state surface water treatment rules require that all surface water supplied for drinking receive filtration, high level disinfection, or both, to inactivate or remove viruses and protozoan cysts such as *Giardia lamblia* and *Cryptosporidium*. However, if a water supply meets certain source water quality criteria and a watershed management program exists to provide protection against these pathogens, the public water purveyor may receive an exemption from the filtration requirements of the federal and state surface water treatment rules. The City and County of San Francisco is an example of a public water purveyor with a current exemption from filtration requirements.

Besides *Giardia* and *Cryptosporidium*, there are many other disease-causing viruses, bacteria, and protozoans. Table 3-24 lists some waterborne diseases in the United States.

Table 3-24. Some Waterborne Diseases of Concern in the United States

Disease	*Microbial Agent*
Amebiasis	Protozoan (*Entamoeba histolytica*)
Campylobacteriosis	Bacterium (*Campylobacter jejuni*)
Cholera	Bacterium (*Vibrio cholerae*)
Cryptosporidiosis	Protozoan (*Cryptosporidium parvum*)
Giardiasis	Protozoan (*Giardia lamblia*)
Hepatitis	Virus (hepatitis A)
Shigellosis	Bacterium (*Shigella* species)
Typhoid Fever	Bacterium (*Salmonella typhi*)
Viral Gastroenteritis	Viruses (Norwalk, rotavirus, and other types)

Disinfection By-Products. As water passes over and through soils, it also dissolves organic compounds present in the soil as a result of plant decay, including humic and fulvic acids. High levels of these compounds can be present in drainage from wooded or heavily vegetated areas and from soils high in organic content. Chlorine, when used as a disinfectant in drinking water treatment, reacts with these organic compounds to form disinfection by-products such as trihalomethanes and haloacetic acids. Table 3-25 lists some potential disinfection by-products, or chemical classes of disinfection by-products, which may be produced during disinfection of drinking water. A maximum contaminant level of trihalomethanes for drinking water has been established by EPA and by DHS, in accordance with the federal and state Safe Drinking Water laws. The current MCL for trihalomethanes in drinking water is 0.10 mg/L; no MCL for haloacetic acids is currently in effect. A stricter MCL of 0.08 mg/L for trihalomethanes and a new MCL of 0.06 mg/L for haloacetic acids are expected to be effective in late 1998, as EPA revises current drinking water standards.

Table 3-25. Disinfectants and Disinfection By-Products

Disinfectant	*Potential Disinfection By-Products or Classes of Disinfection By-Products*
Chlorine	Trihalomethanes
	Halogenated acids
	Haloacetonitriles
	Halogenated aldehydes
	Halogenated ketones
	Chloropicrin
	Chlorinated phenols
Chloramine	Trihalomethanes
	Halogenated acids
	Haloacetonitriles
	Halogenated aldehydes
	Halogenated ketones
	Chloropicrin
	Chlorinated phenols
	Cyanogen chloride
Ozone	Bromate
	Brominated acids
	Formaldehyde
	Acetaldehyde
	Other aldehydes
	Carboxylic acids
	Hydrogen peroxide
Chlorine dioxide	Chlorite
	Chlorate

Ozone is a powerful oxidant widely used for drinking water disinfection. Its advantages are that it efficiently kills pathogenic organisms such as *Giardia* and *Cryptosporidium*, destroys tastes and odors, and minimizes production of trihalomethanes and most other unwanted disinfection by-products. However, bromate is formed during ozone disinfection of waters containing bromide. EPA estimates that bromate may be a more potent carcinogen than trihalomethanes and haloacetic acids. A new MCL of 0.01 mg/L for bromate is expected to be effective in late 1998.

Pollutants in Agricultural and Urban Runoff. Pollutants in runoff from agricultural areas are generally of the nonpoint variety, meaning their sources are usually diffuse and are not readily subject to control. Agricultural runoff may contain chemical residues, trace elements, salts, nutrients, and elevated concentrations of chemicals which are converted to disinfection by-products in drinking water. Pathogens from dairies and livestock operations can enter waterways through agricultural runoff. Sediments from land tillage and forestry activities can enter waterways, obstructing water flow and affecting the survival and reproduction of fish and other aquatic organisms.

Drainage from some agricultural lands in the San Joaquin Valley contains high concentrations of salts and sometimes concentrations of pesticides and trace elements. This water quality problem is exacerbated when salts are recirculated as Delta water is delivered to the San Joaquin Valley to irrigate agricultural lands, and then is returned to the Delta through the San Joaquin River.

Many agencies south of the Delta blend Delta water supplies with other more saline water. When Bay-Delta TDS levels increase, more Bay-Delta water is needed to maintain salinity objectives for blended water supplies and to leach salts from farm fields and urban landscapes. Elevated TDS levels also limit agencies' ability to recycle water. Agencies must meet customer objectives for TDS and comply with discharge requirements. Increased TDS levels may limit their ability to do so. Agencies' ability to store water for future use through groundwater recharge or conjunctive use programs depends on the TDS of the source water. RWQCB Basin Plans generally require that water used for recharge not degrade existing groundwater quality. Increased TDS levels increase salt loadings to groundwater basins and may ultimately limit the use of the existing groundwater.

The TOC level of water is generally a good indication of the amount of DBP precursor present in the water. Rivers passing through the Delta pick up organic matter. For example, as Sacramento River water passed through the Delta, the THM formation potential increases almost threefold by the Delta outflow at the Banks Pumping Plant due to the contribution of agricultural drainage from peat soils.

Under EPA's proposed rule, the maximum contaminant level for THMs will be lowered from 100 to 80 ug/L in Stage 1 and to 40 ug/L in Stage 2. Stage 1 and Stage 2 of the D/DBP

Rule are to be promulgated in November 1998 and May 2002. Compliance with the MCLs for DBPs alone will not be sufficient. Stage 1 of the D/DBP Rule also requires surface water systems using conventional treatment to remove a percentage of the DBP precursosrs in the influent -- as measured by TOC -- in addition to meeting standards for the D/DBPs themselves. The rule proposes that systems achieve a percent TOC removal based on their influent TOC. TOC removal requirements would be 25 percent when the influent TOC is between 2.0 and 4.0 mg/L and 35 percent when the influent TOC is between 4.0 to 8.0 mg/L. Measured TOC concentrations at the Banks Pumping Plant range from 2.1 to 8.6 mg/L.

MWDSC estimates that additional treatment costs to meet the enhanced coagulation requirements for SWP water would be about $26 per acre-foot and about $39 per acre-foot, depending on whether the influent TOC is less than or greater than 4.0 mg/L. MWDSC's current cost to treat SWP water is about $26 per acre-foot.

Pollutants in runoff from urban areas can come from both point and nonpoint sources. Nonpoint sources of pollution include recreational activities, drainage from industrial sites, runoff from streets and highways, discharges from other land surfaces, and aerial deposition. In California, storm water runoff, a major source of nonpoint source pollution, is regulated by SWRCB on behalf of EPA.

Municipal and industrial wastewater discharges are point sources of pollution. Most industries in California discharge to a publicly-owned wastewater treatment plant and only indirectly to the environment. These industries are required to pretreat their industrial waste prior to its discharge to municipal wastewater treatment plants. Like municipal discharges, industrial discharges are subject to regulation through NPDES. Industries discharging directly into the environment are also required to have NPDES permits.

Wastewater treatment facilities operated under NPDES have, in general, been successful in maintaining the quality of California's water bodies. However, the discharge permits do not regulate all constituents that may cause adverse impacts. For example, the discharge of organic materials that contribute to the formation of disinfection by-products in drinking water is not regulated. NPDES does not guarantee elimination of pathogenic organisms such as *Giardia* and *Cryptosporidium*, which are harder to inactivate (disinfect) than most other waterborne pathogens. In addition, permitted discharges can include nitrogen compounds that can be harmful to aquatic life, cause algae growth in surface water bodies, and force downstream drinking water facilities to increase their use of chlorine or to switch to alternative disinfection processes. Some wastewater treatment plant processes do not completely remove all synthetic chemicals that can be present in the water.

The potential for adverse impacts on water quality increases as the number of treatment plants discharging into the waterway increases. For example, 15 major wastewater treatment plants discharge into the Sacramento River watershed and 6 major wastewater treatment plants discharge into the San Joaquin River watershed. These rivers are the two major tributaries which flow into the Delta, a source of drinking water for much of southern California. Table 3-26 lists these wastewater treatment plants and the average daily volume of discharge from each facility into the waterways.

Recently, there has been increasing concern about contamination of drinking water sources by methyl tertiary butyl ether. MTBE is a compound added to gasoline to promote more complete combustion and reduce exhaust emissions. In California, MTBE is used to reduce exhaust emissions and to meet federal Clean Air Act requirements for oxygenated gasoline. MTBE is now being found in wells and reservoirs used for municipal water supply.

Table 3-26. Major Waste Water Treatment Plants Discharging into the Sacramento and San Joaquin Rivers

Facility	Average Flow (mgd)
Sacramento River Basin	
Sacramento Regional	150
Roseville	11.8
Vacaville Easterly	6
West Sacramento	4.5
Davis	3.6
Redding, Clear Creek	3.5
Oroville	3.5
Chico Main	3
University of California	1.8
Grass Valley	1.6
Red Bluff	1.2
Anderson	1.2
Placerville, Hangtown Creek	1.2
Beale AFB	1.1
Olivehurst PUD	1
San Joaquin River Basin	
Stockton Main	29
Turlock	8
Merced	5.5
Tracy	4
Atwater	2.9
EID Deer Creek	1.5
Total	**245.9**

In drinking water, MTBE causes taste and odor problems at low concentrations. EPA has tentatively classified MTBE as a possible human carcinogen, and has issued a draft lifetime health advisory of 70 mg/l in drinking water. In California, an interim action level of 35 mg/l has been issued.

To evaluate the presence of MTBE in drinking water supplies in California, voluntary testing for MTBE was implemented in 1996 by water suppliers in response to a DHS request. In February 1997, a regulation was adopted requiring public drinking water systems to monitor their drinking water sources for MTBE as an unregulated chemical (a chemical for which there is no established regulatory or enforceable drinking water level or maximum contaminant level). Because MTBE is an unregulated chemical, water suppliers will be monitoring and reporting MTBE in sources of drinking water at least once every three years.

The most extensive MTBE contamination of drinking water sources in California was at two well fields (Charnock and Arcadia) in Santa Monica. This contamination was discovered in February 1996, not long after DHS' request for voluntary testing for MTBE. These well fields supplied 80 percent of Santa Monica's municipal water. MTBE concentrations as high as 610 mg/l were observed in the Charnock well field and seven wells in the field were closed. In the Arcadia well field, two wells were closed due to contamination from an underground storage tank at a nearby gasoline station.

As noted in Chapter 2, legislation enacted in 1997 required DHS to begin adopting primary and secondary drinking water standards for MTBE. The secondary drinking water standard for MTBE is to be established by July 1, 1998, and the primary drinking water standard is to be

quatic organisms and has been
ne Sacramento River. Turbidity
ions. Significant turbidity
igh storm runoff. Phytoplankton
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through adoption of region-specific water quality control plans, commonly known as basin plans. In general, water quality control plans designate beneficial uses of water and establish water quality objectives designed to protect them. The designated beneficial uses of water may vary between individual water bodies; some are listed in Table 3-27.

Table 3-27. A Partial List of Potential Beneficial Uses of Water

Municipal and Domestic Supply
Agricultural Supply
Industrial Supply
Groundwater Recharge
Freshwater Replenishment
Navigation
Hydropower Generation
Recreation
Commercial and Sport Fishing
Aquaculture
Freshwater Habitat
Estuarine Habitat
Wildlife Habitat
Preservation of Biological Habitats of Special Significance
Preservation of Rare, Threatened, or Endangered Species
Migration of Aquatic Organisms
Spawning, Reproduction, and/or Early Development
Shellfish Harvesting

Water quality objectives are the limits or levels of water quality constituents or characteristics which are established to protect beneficial uses. Because a particular water body may have several beneficial uses, the water quality objectives established must be protective of all designated uses. When setting water quality objectives, several sources of existing water quality limits are used (see Table 3-28), depending on the uses designated in a water quality control plan. When more than one water quality limit exists for a water quality constituent or characteristic (e.g., human health limit vs. aquatic life limit), the more restrictive limit is used as the water quality objective. Table 3-29 lists some typical water quality constituents or characteristics for which water quality objectives may be established in water quality control plans.

Table 3-28. A Partial List of Existing Water Quality Limits

Drinking Water Maximum Contaminant Levels
Drinking Water Maximum Contaminant Level Goals
State Action Levels and Recommended Public Health Levels for Drinking Water
EPA Health Advisories and Water Quality Advisories
National Academy of Sciences Suggested No-Adverse-Response Levels
Proposition 65 Regulatory Levels
EPA National Ambient Water Quality Criteria

Table 3-29. A Partial List of Water Quality Constituents or Characteristics for Which Water Quality Objectives May Be Established

Chemical Constituents	Pesticides
Tastes and Odors	pH
Human Health and Ecological Toxicity	Radioactivity
Bacteria	Salinity
Biostimulatory Substances	Sediment
Color	Settleable Material
Dissolved Oxygen	Suspended Material
Floating Material	Temperature
Oil and Grease	Turbidity

Drinking Water Standards

Drinking water standards for a total of 81 individual drinking water constituents (see Table 3-30) are in place under the mandates of the 1986 SDWA amendments. By the new SDWA standard setting process established in the 1996 amendment, EPA will select at least five new candidate constituents to be considered for regulation every five years. Selection of the new constituents for regulation must be geared toward contaminants posing the greatest health risks.

Table 3-30. Constituents Regulated Under the Federal Safe Drinking Water Act[1]

1,1-Dichloroethylene	Chromium	Methoxychlor
1,1,1-Trichloroethane	cis-1,2-Dichloroethylene	Nickel
1,1,2-Trichloroethane	Copper	Nitrate
1,2-Dibromo-3-chloropropane (DBCP)	Cyanide	Nitrite
1,2-Dichlorobenzene	Dalapon	Oxamyl
1,2-Dichloroethane	Dichloromethane	Pentachlorophenol
1,2-Dichloropropane	Dinoseb	Phthalates
1,2,4-Trichlorobenzene	Diquat	Picloram
1,4-Dichlorobenzene	Endothall	Polychlorinated biphenyls (PCBs)
2,3,7,8-TCDD (Dioxin)	Endrin	Polynuclear Aromatic Hydrocarbons (PAHs)
2,4-Dichlorophenoxyacetic acid (2,4-D)	Epichlorohydrin	Radium 226
2,4,5-TP (Silvex)	Ethylbenzene	Radium 228
Acrylamide	Ethylene dibromide (EDB)	Selenium
Adipates	Fluoride	Simazine
Alachlor	Giardia lamblia	Styrene
Antimony	Glyphosate	Tetrachloroethylene
Arsenic	Gross alpha particle activity	Thallium
Asbestos	Gross beta particle activity	Toluene
Atrazine	Heptachlor	Total coliforms
Barium	Heptachlor epoxide	Total trihalomethane
Benzene	Heterotrophic bacteria	Toxaphene
Beryllium	Hexachlorobenzene	trans-1,2-Dichloroethylene
Cadmium	Hexachlorocyclopentadiene	Trichloroethylene
Carbofuran	Lead	Turbidity
Carbon tetrachloride	Legionella	Vinyl chloride
Chlordane	Lindane	Viruses
Chlorobenzene	Mercury	Xylenes (total)

[1] As of February 1997.

Occasionally, drinking water regulatory goals may conflict. For example, concern over pathogens such as *Cryptosporidium* spurred a proposed rule requiring more rigorous disinfection. At the same time, there was considerable regulatory concern over trihalomethanes and other disinfection by-products resulting from disinfecting drinking water with chlorine. However, if disinfection is made more rigorous, disinfection by-product formation is increased. Poor quality source waters with elevated concentrations of organic precursors and bromides further complicate the problem of reliably meeting standards for disinfection while meeting standards for disinfection by-products. The regulatory community will have to balance the benefits and risks associated with pursuing the goals of efficient disinfection and reduced disinfection by-products.

EPA promulgated its Information Collection Rule in 1996 to obtain the data on the tradeoff posed by simultaneous control of disinfection by-products and pathogens in drinking water. The Information Collection Rule requires all large public water systems to collect and report data on the occurrence of disinfection by-products and pathogens (including bacteria, viruses, *Giardia*, and *Cryptosporidium*) in drinking water over an 18-month period. With this information, an assessment of health risks due to the presence of disinfection by-products and pathogens in drinking water can be made. EPA can then determine the need to revise current drinking water filtration and disinfection requirements, and the need for more stringent regulations for disinfectants and disinfection by-products.

Source Water Protection/Watershed Management Activities

The source water protection program established in the 1996 SDWA amendments is part of a multiple barrier approach to drinking water protection that includes SWPP monitoring. SWPP is intended to delineate the watersheds of all public drinking water sources -- both surface and groundwater-- identify sources of contamination within each watershed, and determine the susceptibility of drinking water sources to the contaminants present. States must submit their SWPPs to EPA for approval before implementing their programs. SDWA provides funding to implement the SWPP through a set-aside from the SRF. Once the SWPP is implemented, states may provide loans to local agencies that establish voluntary partnerships to protect drinking water sources.

The potential sources and causes of water quality impairment vary from watershed to watershed. A comprehensive source water protection and watershed management program will identify and address all sources and causes within the watershed. Table 3-31 lists potential sources and causes of water quality impairment in a watershed.

Table 3-31. Potential Sources and Causes of Water Quality Impairment

Source of Contamination	Pollutant or Stressor	Possible Sources
Natural (occur statewide)	Dissolved minerals	Mineral deposits, mineralized waters, hot springs, sea water intrusion
	Asbestos	Mine tailings, serpentinite formations
	Hydrogen sulfide	Subsurface organic deposits, such as peat soils in Delta islands
	Metals	Mine tailings
	Microbial agents	Wildlife
	Radon	Geologic formations
	Sediment	Forestry activities, stream banks, construction activities, roads, mining operations, gullies
	Altered flow or habitat modification	Impoundments, storm water runoff, artificial drainage, bank erosion, riparian corridor modification
Commercial Businesses	Gasoline	Service stations' underground storage tanks
	Solvents	Dry cleaners, machine shops
	Metals	Photo processors, laboratories, metal plating works
Municipal	Microbial agents	Sewage discharges, storm water runoff
	Pesticides	Storm water runoff, golf courses
	Nutrients	Storm water runoff
	Miscellaneous liquid wastes	Industrial discharge, household waste, septic tanks
Industrial	VOCs, industrial solvents, metals, acids	Electronics manufacturing, metal fabricating and plating, transporters, storage facilities, hazardous waste disposal
	Pesticides	Chemical formulating plants
	Wood preservatives	Plants that treat pressure treating power poles, wood pilings, railroad ties
Solid Waste Disposal	Solvents, pesticides, metals, organics, petroleum wastes, microbial agents	Disposal sites receive waste from a variety of industries, municipal solid wastes, wasted petroleum products, household waste
Agricultural	Pesticides, fertilizers, concentrated mineral salts, microbial agents, sediment, nutrients	Tailwater runoff, agricultural chemical applications, fertilizer usage, chemical storage at farms and applicators' air strips, packing sheds and processing plants, dairies, feed lots, pastures
Disasters	Solvents, petroleum products, microbial agents, other hazardous materials	Earthquake-caused pipeline and storage tank failures and damage to sewage treatment and containment facilities, major spills of hazardous materials, flood water contamination of storage reservoirs and groundwater sources

A Source Water Protection Example. DHS requested that the Department perform a sanitary survey of the SWP. The Department's 1990 initial survey and 1996 update provide an example of factors considered in source protection studies. Table 3-32 lists some recommendations for action resulting from the sanitary survey.

Table 3-32. State Water Project Sanitary Survey Update Recommendations

Water Quality Problem	*Recommendation*
Pathogenic Organisms	Implement pathogen monitoring program to evaluate risk of pathogens in State Water Project waters
Disinfection By-Product Precursors (Organic Carbon)	Investigate possible means of reducing organic carbon levels in the Delta and North Bay Aqueduct
Disinfection By-Product Precursors (Bromide)	Investigate possible means of controlling bromide concentrations in State Water Project waters
Dissolved Solids and Turbidity in the California Aqueduct	Measures to reduce salts and turbidity in the Aqueduct should be investigated
Hazardous Waste Facilities	An inventory of hazardous waste facilities and volume of hazardous materials should be obtained and reviewed
Hazardous Materials Releases	Incidences of emergency responses to hazardous materials should be reviewed to determine types/amounts of materials released and potential for contamination in watershed
Urban Runoff	Storm water monitoring in cities and urbanized areas should be reviewed to determine extent of discharge of contaminants
Barker Slough/North Bay Aqueduct	Intensive study of the watershed should be conducted to determine sources and extent of contamination and to identify possible corrective measures
Solid Waste Landfills	A comprehensive review of solid waste landfills in State Water Project watersheds should be conducted
Underground Storage Tanks	Evaluation of status of leaking underground storage tanks within State Water Project watersheds should be performed
Petroleum Product Pipelines	Incidences of pipeline failures resulting in petroleum releases should be reviewed to determine potential for State Water Project water contamination
Emergency Action Plan	Emergency Action Plan for the State Water Project should be reviewed to ensure document is up-to-date and functionally adequate

The 1996 sanitary survey identified the need to address pathogenic organisms, such as *Giardia* and *Cryptosporidium,* in SWP waters. Recommendations were made to further investigate each watershed tributary to the SWP to evaluate the potential sources of pathogenic organisms and to develop a coordinated microbiological monitoring and reporting system for municipal SWP contractors and agencies. The Department and MWDSC have implemented a pathogen monitoring program. Under this program, regularly scheduled and storm event sampling for *Giardia*, *Cryptosporidium*, and bacteria which serve as general indicators of microbiological contamination (such as *Clostridium perfringens*, *Escherichia coli*, and total and fecal coliforms) is conducted at sites throughout the SWP.

CALFED Bay-Delta Program Water Quality Planning. CALFED's objective for water quality is to provide good water quality for urban, agricultural, industrial, environmental, and recreational beneficial uses. To achieve this objective, CALFED will recommend strategies that address water quality parameters identified as a concern to beneficial uses.

Through public workshops, CALFED developed a comprehensive list of water quality parameters of concern in the Bay-Delta watershed (see Table 3-33). This list was developed so water quality impacts to the estuary's five major beneficial uses of water (environment, urban, agriculture, recreation, and industrial) can be evaluated as proposed solutions for the Bay-Delta are considered. To help evaluate water quality improvements, CALFED set target values for each water quality parameter of concern. These water quality targets were based on existing regulatory criteria or other appropriate objectives where regulatory criteria do not exist.

CALFED developed strategies to address water quality parameters of concern in the Delta and its tributaries. The strategies are recommended actions that improve water quality by reducing loadings from the sources of water quality problems or changing water management practices. Action strategies to address water quality problems include a combination of research, pilot studies, and full-scale actions. Some of the action strategies being considered by CALFED include:

- Reducing pollutant concentrations entering the Delta from the San Joaquin River.
- Reducing vulnerability of Delta water quality to salinity intrusion by implementing the Delta Long-Term Protection Plan (including maintenance of Delta levees).
- Improving water circulation in the Delta by constructing seasonally-operated barriers in south Delta channels.
- Promoting and supporting efforts of local watershed programs that improve the water quality within the Delta and its tributaries.
- Reducing the load of metals from mine drainage entering the Delta and its tributaries.
- Reducing urban and industrial pollutants entering the Delta and its tributaries by controlling urban and industrial runoff.
- Controlling discharges of domestic wastes from boats within the Delta and its tributaries.

- Identifying and implementing actions to address contaminants in water and sediment within the Delta and its tributaries.
- Reducing pollutants entering the Delta and its tributaries from agricultural runoff.

Table 3-33. CALFED Bay-Delta Water Quality Parameters of Concern

Environment	Urban	Agriculture	Recreation	Industrial
Metals and Toxic Elements	Disinfection By-Product Precursors	Boron	Metals	Salinity
Cadmium	Bromide	Chloride	Mercury	pH
Copper	Total Organic Carbon	Nutrients (Nitrate)		Alkalinity
Mercury		pH (Alkalinity)	Organics/Pesticides	Phosphates
Selenium	Other	Salinity (TDS, EC)	PCBs	Ammonia
Zinc	Nutrients (Nitrate)	Sodium Adsorption Ratio	DDT	
	Pathogens	Turbidity		
Organics/Pesticides	Salinity (TDS)	Temperature	Other	
Carbofuran	pH		Pathogens	
Chlordane	Turbidity		Nutrients	
Chlorpyrifos				
DDT				
Diazinon				
PCBs				
Toxaphene				
Other				
Ammonia				
Dissolved Oxygen				
Salinity (TDS, EC)				
Temperature				
Turbidity				
Toxicity				

Colorado River Water Quality. The Colorado River is a major source of water supply to Southern California. The river is subject to various water quality influences because its watershed is so large. Much of the watershed is open space and agricultural lands, and municipal and industrial discharges are not a significant source of water quality degradation. Salts and turbidity from natural geologic formations and from agricultural operations are the primary forms of water quality degradation. Unlike the watersheds of the Delta, the soils of the Colorado River watershed are low in organic content. As a result, water from the Colorado River typically has only about one-half the capacity to produce disinfection by-products during drinking water treatment as does water from the Delta.

Mineral concentrations in the Colorado River are usually much higher than those found in the water taken from the Delta. For example, from 1993 to 1995, the average concentration of dissolved solids in MWDSC's Colorado River Aqueduct was 691 mg/L, while the average concentration in the California Aqueduct was 236 mg/L. When possible, MWDSC blends Colorado River water with SWP water or other sources to reduce the salt concentrations in the water delivered to customers.

The federal Colorado River Basin Salinity Control Act of 1974 authorized construction of facilities to control Colorado River salinity to meet salinity requirements expressed in Minute 242 of the U.S. - Mexican Treaty. Currently, salinity control activities are removing over 600,000 tons of salt per year from the river system. However, to maintain the 1975 federally approved salinity standards for the basin, it is estimated that by the year 2010, approximately 1.5 million tons of salt will have to be removed each year. An example of a salinity control feature in the basin is USBR's Yuma desalting plant, constructed to treat agricultural drainage from Arizona's Wellton-Mohawk Irrigation and Drainage District that had substantially increased river salinity. The plant, said to be the world's largest reverse osmosis desalter, has a capacity of 75 mgd. Plant construction was completed in the early 1990s, but the facility has not been operated in a production mode due to cost considerations. (Current levels of river flow and USBR's bypass of an Arizona agricultural drainage canal are enabling treaty water quality requirements to be met without use of the desalter.)

Groundwater Quality

There has been growing concern over the potential human health threat of pathogens in groundwater used as drinking water. This concern stems from pathogens such as *Giardia*, *Cryptosporidium*, bacteria, and viruses being found in water taken from wells. Several waterborne-disease outbreaks associated with groundwater used as a source of drinking water have been reported outside California. Some of these outbreaks are listed in Table 3-34.

Table 3-34. Waterborne-Disease Outbreaks Associated with Groundwater Used as a Drinking Water Source, 1993-1994

State	Month/Year	Pathogenic Organism	Organism Type	No. of Cases
Minnesota	November 1993	*Campylobacter jejuni*	Bacterium	32
Missouri	November 1993	*Salmonella* serotype *Typhimurium*	Bacterium	625
New York	June 1993	*Campylobacter jejuni*	Bacterium	172
Pennsylvania	January 1993	*Giardia lamblia*	Protozoan	20
South Dakota	September 1993	*Giardia lamblia*	Protozoan	7
Washington	April 1993	*Cryptosporidium parvum*	Protozoan	7
Idaho	June 1994	*Shigella flexneri*	Bacterium	33
Minnesota	June 1994	*Campylobacter jejuni*	Bacterium	19
New York	June 1994	*Shigella sonnei*	Bacterium	230
Washington	August 1994	*Cryptosporidium parvum*	Protozoan	134

The concern about pathogens in groundwater has led to regulatory discussions on disinfection requirements for groundwater. It is currently estimated that the Groundwater Disinfection Rule will be proposed sometime in 1999 and will become effective in 2002. The risks to human health posed by the presence of these pathogens in groundwater supplies have not yet been determined. The data obtained through the Information Collection Rule will provide the necessary information to assess the extent and severity of risk.

The SDWA requires states to implement wellhead protection programs designed to prevent the contamination of groundwater supplying public drinking water wells. Wellhead protection programs rely heavily on local efforts to be effective, because communities have the primary access to information on potential contamination sources and can adopt locally-based measures to manage these potential contamination sources. EPA has recommended five steps that communities can take to implement wellhead protection:

- Form a community planning organization.
- Define the land area around the well to be protected.
- Identify potential sources of contamination within the area.
- Develop and implement a management plan to protect the area.
- Plan for emergencies and future water supply needs.

Water Supply Summary by Hydrologic Region

This chapter described how the State's water supplies are affected by climate and hydrology, how water supplies are calculated, and how water supplies are reallocated through storage and conveyance facilities and through water transfers. Also, this chapter discussed water quality considerations that affect beneficial uses of California's water supplies.

Table 3-35 summarizes average year water supplies by hydrologic region assuming existing 1995 and future 2020 levels of development and existing facilities and programs. Similarly, Table 3-36 summarizes drought year water supplies by hydrologic region for existing and future levels of development. Regional water supplies, along with water demands presented in the following chapter, provide the basis for regional water budgets developed in Chapters 7 through 9 and the statewide water budget developed in Chapter 10.

Table 3-35. California Average Year Water Supplies by Hydrologic Region [1] (with existing facilities and programs, in taf per year)

Region	1995				2020			
	Surface	Groundwater[2]	Recycled	Total	Surface	Groundwater[2]	Recycled	Total
North Coast	20,331	263	13	20,607	20,371	288	13	20,672
San Francisco Bay	7,011	68	35	7,115	7,067	74	35	7,176
Central Coast	308	1,045	18	1,371	367	1,029	42	1,437
South Coast	3,770	1,177	207	5,155	3,764	1,196	328	5,288
Sacramento River	11,873	2,672	0	14,545	12,188	2,636	0	14,824
San Joaquin River	7,468	2,195	0	9,663	7,364	2,323	0	9,687
Tulare Lake	7,968	4,340	0	12,308	7,871	4,386	0	12,257
North Lahontan	1,038	157	8	1,203	1,020	183	8	1,211
South Lahontan	322	239	27	587	545	227	27	799
Colorado River	4,154	337	15	4,506	4,023	251	15	4,288
Totals (rounded)	**64,240**	**12,490**	**320**	**77,060**	**64,580**	**12,590**	**470**	**77,640**

[1] Average year water supply data shown as applied water.

[2] Excludes groundwater overdraft.

Table 3-36. California Drought Year Water Supplies by Hydrologic Region [1] (with existing facilities and programs, in taf per year)

	1995				2020			
Region	*Surface*	*Groundwater* [2]	*Recycled*	*Total*	*Surface*	*Groundwater* [2]	*Recycled*	*Total*
North Coast	10,183	294	14	10,491	10,212	321	14	10,546
San Francisco Bay	5,285	92	35	5,412	53,280	91	35	5,454
Central Coast	150	1,142	26	1318	183	1,145	42	1,369
South Coast	3,085	1,371	207	4,664	3,084	1,422	328	4,835
Sacramento River	10,021	3,218	0	13,238	10,011	3,281	0	13,292
San Joaquin River	5,559	2,900	0	8,459	5,502	2,912	0	8,414
Tulare Lake	3,711	5,970	0	9,681	3,611	5,999	0	9,610
North Lahontan	642	187	8	837	642	208	8	858
South Lahontan	259	273	27	559	441	279	27	747
Colorado River	4,128	337	15	4,479	4,013	250	15	4,278
Totals (rounded)	**43,020**	**15,780**	**330**	**59,140**	**43,030**	**15,910**	**470**	**59,400**

[1] Drought year water supply data shown as applied water.

[2] Excludes groundwater overdraft.

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Chapter 4. Urban, Agricultural, and Environmental Water Use

This chapter reviews present and forecasted demands for urban, agricultural, and environmental water use, and updates data presented in the 1993 California Water Plan Update. The chapter is organized into three major sections, one for each category of water use. Some background information associated with these water uses, but not part of the calculation of present and forecasted demands, is presented in the Chapter 4 appendix.

Water demand information is presented at the hydrologic region level of detail. The base year for present water use is 1995. The Bulletin 160-98 planning horizon extends to 2020, as did the planning horizon for the 1993 Bulletin. Forecasted 2020-level urban and agricultural water demands have not changed greatly since publication of the last Bulletin five years ago. Forecasted urban water demands depend heavily on population forecasts. Although the Department of Finance has updated its California population projections since the last Bulletin, U.S. Census data are an important foundation for the projections, and a new census will not be performed until 2000. The Department's forecasts of agricultural demands tend to change fairly slowly in the short-term, because the corresponding changes in forecasted agricultural acreage are a small percentage of the State's total irrigated acreage.

There have been changes in base year and forecasted environmental water demands from the last Bulletin, reflecting implementation of SWRCB's Order WR 95-6 for the Bay-Delta, and emphasis given to evaluating future environmental demands in forums such as the CALFED Bay-Delta program and the CVPIA's AFRP. In the prior Bulletin, calculation of future environmental demands was based only on required Bay-Delta outflow, flows in wild and scenic rivers, required instream flows, and water needs of managed freshwater wildlife refuges. The current Bulletin includes proposed instream flow demands, as available, from CALFED's and AFRP's planning processes.

Summary of Key Statistics

Shown below for quick reference are some key statistics presented in this chapter. For the water use information, values shown are for average water year conditions. The details behind the statistics are discussed later.

1995 California population	32.1 million
2020 California population forecast	47.5 million
1995 California irrigated crop acreage	9.5 million acres
2020 California irrigated crop acreage forecast	9.2 million acres
1995 urban water use	8.8 maf
2020 urban water use forecast	12.0 maf
1995 agricultural water use	33.8 maf
2020 agricultural water use forecast	31.5 maf
1995 environmental water use	36.1 maf
2020 environmental water use forecast	37.0 maf

	1995	2020
Urban Water Use	11%	15%
Agricultural Water Use	43%	39%
Environmental Water Use	46%	46%
Total California Water Use	**100%**	**100%**

Calculation of Water Demands

The urban, agricultural, and environmental water demands calculated in this chapter are combined with Chapter 3 water supply information to form the regional water budgets shown in Chapters 7-9, and the California water budget shown in Chapter 10. As noted in the Chapter 3 discussion of water supplies, Bulletin 160-98 water budgets are being computed with applied water data, rather than the net water data used in previous editions of the Bulletin.

Another change from Bulletin 160-93 was the elimination of the "Other" water demand category. Water uses previously categorized as "Other" are now included in urban, agricultural, or environmental water use according to their intended purpose. In previous Bulletin 160 updates, the "Other" category included major canal conveyance losses, recreation use, cooling water use, energy recovery use, and use by high water using industries. At a statewide level, the magnitude of these other uses is small in comparison to that of the major categories.

The definitions shown below are important to understanding the water demand information presented in this chapter. Following the definitions, Figures 4-1 and 4-2 provide examples of how the definitions are used.

***Applied Water Demand*:** The amount of water from any source needed to meet the demand of the user. It is the quantity of water delivered to any of the following locations:

- the intake to a city water system or factory
- the farm headgate or other point of measurement
- a managed wetland, either directly or by drainage flows.

For existing instream use, applied water demand is the quantity of stream flow dedicated to: instream use (or reserved under the federal or state Wild and Scenic Rivers acts); repelling salinity; or maintaining flows in the San Francisco Bay/Delta pursuant to the State Water Resources Control Board's standards.

Net Water Demand: The amount of water needed in a water service area to meet all demands. It is the sum of evapotranspiration of applied water in an area; the irrecoverable losses from the distribution system; and agricultural return flow or treated municipal outflow leaving the area.

***Irrecoverable Losses*:** The water lost to a salt sink or lost by evaporation or evapotranspiration from a conveyance facility, drainage canal, or in fringe areas.

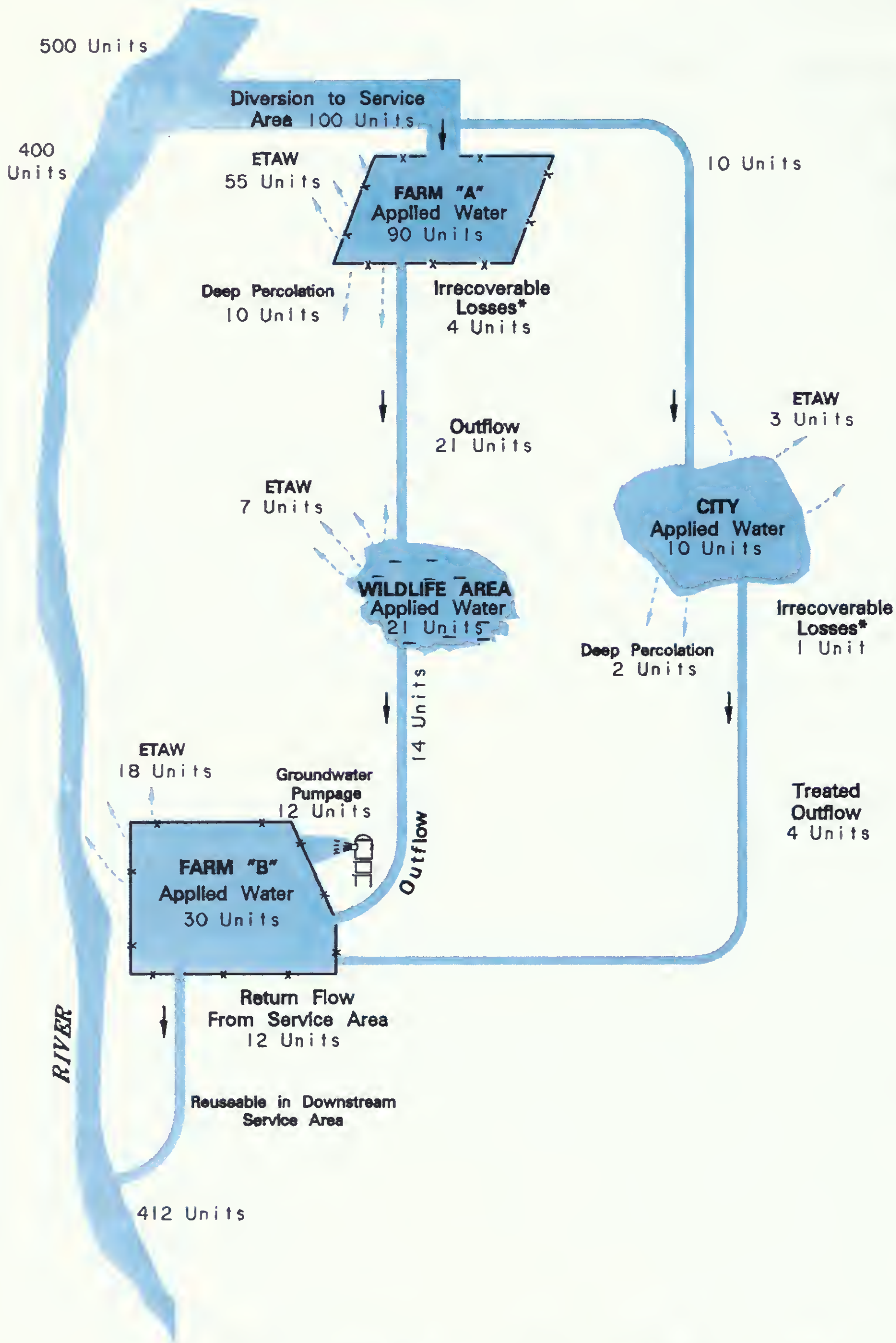
***Depletion*:** The water consumed within a service area and no longer available as a source of supply. For agriculture and wetlands, it is ETAW (and ET of flooded wetlands) plus irrecoverable losses. For urban water use, it is ETAW (water applied to landscaping or home gardens), sewage effluent that flows to a salt sink, and incidental evapotranspiration losses. For instream use, it is the amount of dedicated flow that proceeds to a salt sink.

***Evapotranspiration (*ET_o*)*: the quantity of water transpired (given off), retained in plant tissues, and evaporated from plant tissues and surrounding soil surfaces.

***Evapotranspiration of applied water (ETAW)*:** the portion of the total evapotranspiration which is provided by irrigation.

Figure 4-1. Derivation of Applied Water, Net Water Use, and Depletion

Water Use in Inland Area



	Farm "A"	Wildlife Area	City	Farm "B"	TOTAL
Applied Water	90	21	10	30	151
ETAW	55	7	3	18	83
Irrecoverable Losses*	4	0	1	0	5
Depletion	59	7	4	18	88

ETAW = EVAPOTRANSPIRATION OF APPLIED WATER

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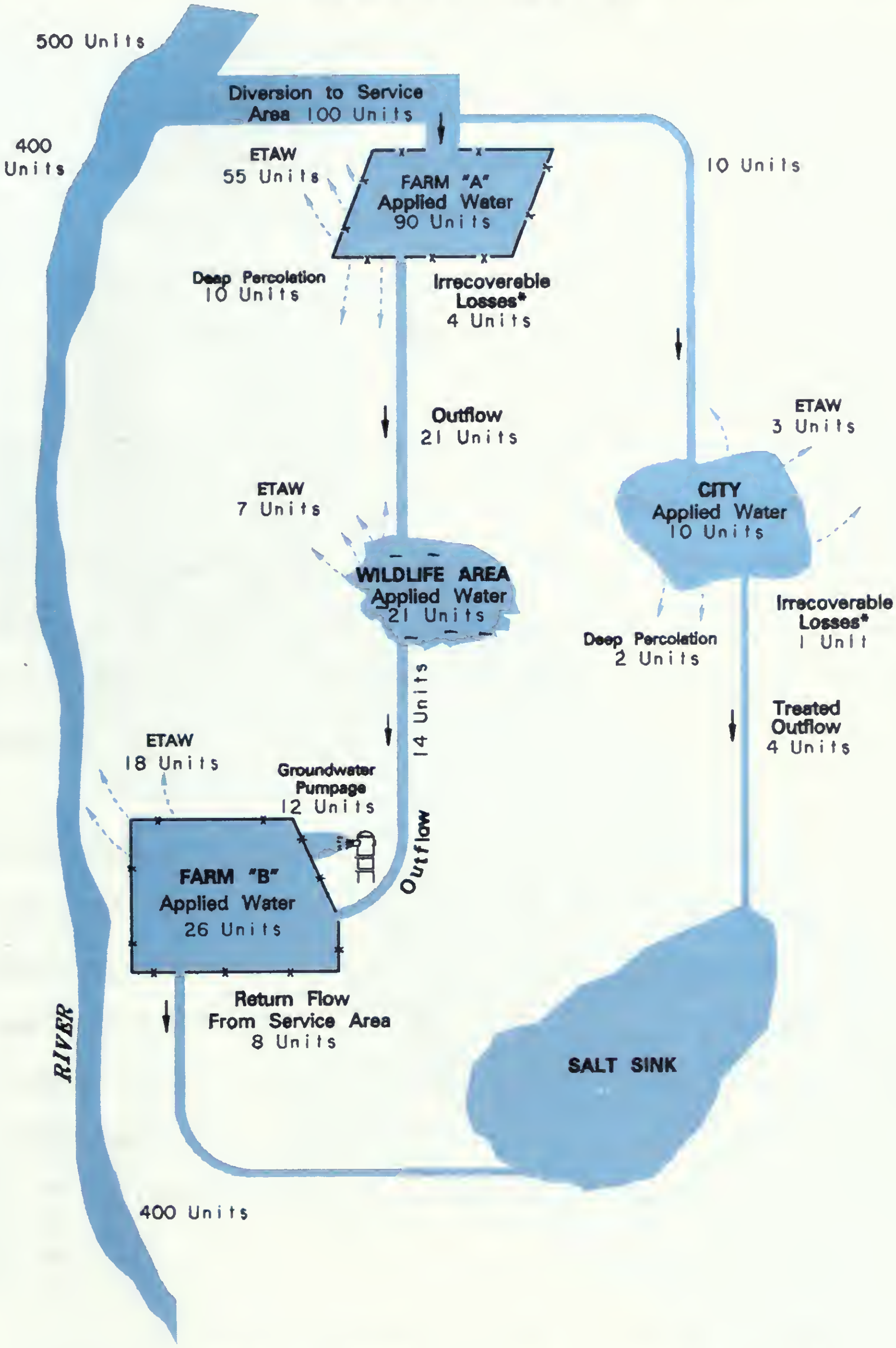
Figure 4-2. Derivation of Applied Water, Net Water Use, and Depletion
Water Use in Coastal Area



	Farm "A"	Wildlife Area	City	Farm "B"	TOTAL
Applied Water	90	21	10	26	147
ETAW	55	7	3	18	83
Irrecoverable Losses*	4	0	5	8	17
Depletion	59	7	8	26	100

ETAW = EVAPOTRANSPIRATION OF APPLIED WATER

Urban Water Use

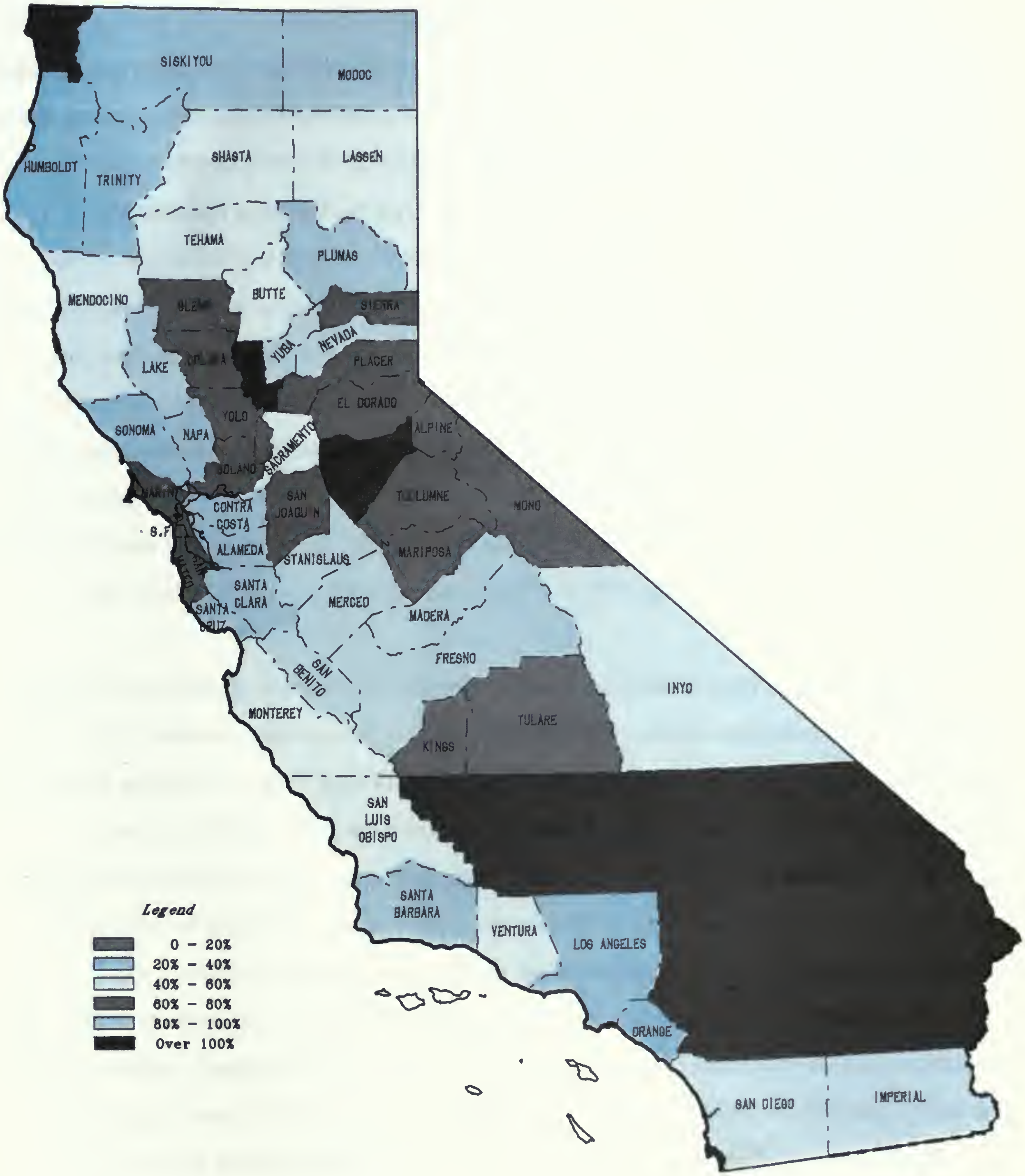
Forecasts of future urban water use for the Bulletin are based on population information and per capita water use estimates, as described in this section. Factors influencing per capita water use include expected demand reduction due to implementation of water conservation programs. The Department has modeled effects of conservation measures and socioeconomic changes on per capita use in 20 major water service areas, so that future changes in per capita use by hydrologic region can be estimated.

This Bulletin makes per capita water use estimates at a statewide level of detail. An urban water agency making such estimates for its own service area would be able to incorporate more complexity in its forecasting, because the scope of its effort is narrow. For this reason, and because California Department of Finance population projections seldom exactly match population projections prepared by cities and counties, the Bulletin's per capita water use values are expected to be representative of, rather than identical to, those of local water agencies.

Population Growth

Bulletin 160-98 uses year 2020 for its planning horizon, as did Bulletin 160-93. Both bulletins relied on information generated in the 1990 United States census. The census, conducted every 10 years, is a major benchmark for population projections. The California Department of Finance works from the decadal census to calculate the State's population in noncensus years, and to project future populations. Figure 4-3 shows DOF's currently projected growth rates by county for year 2020. (State policy requires that all state agencies use DOF population projections for planning, funding, and policymaking activities.)

Figure 4-3. Projected Growth Rates by County, 1995 to 2020



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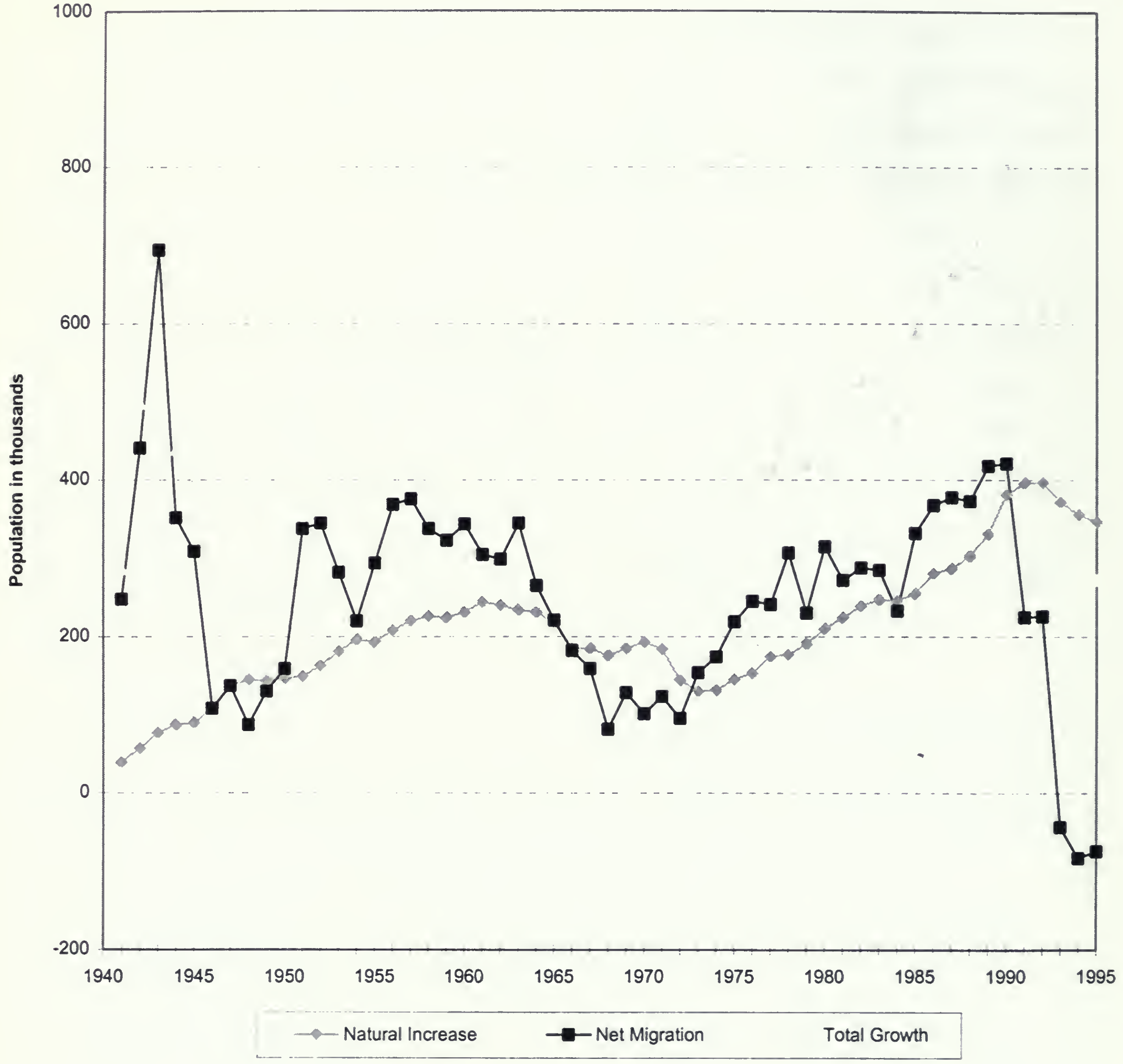
DOF uses as its starting population the 1990 census, as modified by the Bureau of the Census for known misreporting. (These counts represent a modification to the age distribution of the census count and not an adjustment for undercount to the total.) Although between 1950 and 1980 the birthrate in California and in the nation was similar, a sharp divergence began during the 1980s. While the nation's birthrate was flat, the birthrate in California rose sharply.

California's annual growth rate was 2 to 3 percent throughout the 1980s. Since 1990, however, the rate slowed to 1.3 percent and the State's population grew by only 2 million, for a total 1995 population of 32.1 million. A lower than projected natural increase (births minus deaths) and net migration have affected California's growth since 1992. Domestic migration patterns tend to parallel the unemployment differential rate between California and other states. Between 1990-94, California lost more than 700,000 jobs due to the economic recession. This job loss resulted in a new demographic phenomenon for California--a net migration of California residents to other states. By spring 1996, California had replaced the jobs lost during the recession.

Migration is the most volatile component of population change. Migrants are separated into two categories: domestic (from other states) or foreign (from other countries). Since 1980, approximately 30 percent of net migration has been domestic and 70 percent foreign. Since 1970, annual migration has fluctuated from less than 100,000 to more than 450,000. The wide fluctuations are primarily attributed to domestic migration, since undocumented migration has been fairly constant and legal foreign migration has slowly increased. Figure 4-4 shows the components of growth, natural increase and net migration, for the years 1940 to 1995.

Data about California's population--its geographic distribution and projections of future population and their distribution-- come from several entities. The Department works with base year and projected year population information developed by the DOF for each county in the State. DOF uses a baseline cohort-component method to project population by gender, race/ethnicity, and age. A baseline projection assumes people have the right to migrate where they choose and no major natural catastrophes or wars will occur. A cohort-component method traces people born in a given year throughout their lives. As each year passes, cohorts change due to mortality and migration assumptions. New cohorts are formed by applying birthrate assumptions to women of childbearing age. Special populations display different demographic behavior and other characteristics and must be projected separately. The primary sources of special populations are prisons, colleges, and military installations.

Figure 4-4. Components of Population Growth, 1940-1995



Population projections used in this Bulletin are based on DOF's Special Interim Population Projections for the Department of Water Resources (May 1996). Table 4-1 shows the 1995 through 2020 population figures for Bulletin 160-98 by hydrologic region.

The Department allocated county population data to Bulletin 160 study areas based on watershed or water district boundaries. Factors considered in distributing the data to Bulletin 160 study areas include population projections prepared by cities, counties, and local Councils of Governments, which typically incorporate future development envisioned in city and county general plans. These local agency projections indicate which areas within a county are expected to experience growth, and provide guidance in allocating DOF's projection for an entire county into smaller Bulletin 160 study areas. Table 4-2 compares DOF Special Interim Projections with Councils of Governments and County projections.

Table 4-1. California Population by Hydrologic Region
(in millions)[a]

Hydrologic Regions	*1995*	*2020*
North Coast	0.6	0.8
San Francisco Bay	5.8	7.0
Central Coast	1.3	1.9
South Coast	17.3	24.3
Sacramento River	2.4	3.8
San Joaquin River	1.6	3.0
Tulare Lake	1.7	3.3
North Lahontan	0.1	0.1
South Lahontan	0.7	2.0
Colorado River	0.5	1.1
California Total	**32.1**	**47.5[b]**

a Columns may not sum due to independent rounding.

b For comparison, Bulletin 160-93 forecasted a 2020 population of 48.9 million, 1.4 million people higher than this Bulletin's 2020 forecast.

Table 4-2. Comparison Between Department of Finance Special Interim and Councils of Governments Projections

	Census 1990	July 2010[a]	
		DOF	COG
Southern California Counties	17,138,848	23,351,500	24,038,300
Bay Area Counties	6,020,147	7,488,900	7,539,600
Central Coast Counties	1,172,164	1,507,600	1,517,500
Greater Sacramento Counties	1,683,463	2,541,800	2,586,000
San Joaquin Valley Counties	2,742,000	4,607,800	4,640,500

a Councils of Governments data were only available for 2010, thus 2010 COG forecasts are compared with B160-98 2010 projections.

Factors Affecting Urban Per Capita Water Use

Urban per capita water use includes residential, commercial, industrial, and institutional uses of water. Each of these categories can be broken down into greater levels of detail. Residential water use, for example, includes interior and exterior (e.g., landscaping) water use. At a site-specifc level of detail for an individual community, it is possible to break down urban water use into components and forecast each component separately. It is not possible to use this level of detail for each community in the State at the level of forecasting performed for Bulletin 160-98. Instead, we have modeled components of urban use for representative urban water agencies in each of the State's ten hydrologic regions and have extrapolated those results to the remainder of each hydrologic region, as described later in the chapter.

Assumptions about demand reduction achieved through implementation of water conservation measures are an important part of per capita water use forecasts. Bulletin 160-98 incorporates demand reductions from implementation of urban best management practices contained in the 1991 Memorandum of Understanding for Urban Water Conservation. We assume implementation of the urban MOU's BMPs by 2020, which would result in a demand reduction of about 1.5 maf over year 2020 without BMP implementation. The following subsections provide more detail on demand reduction achieved through water conservation, and existing urban water conservation programs.

The relationship of water pricing to water consumption, and the role of pricing in achieving water conservation, has been a subject of discussion in recent years. Urban water rates in California vary widely, with geographic location having a major influence. Water rates are set by local agencies to recover their costs of providing water service, and are highly site-specific. Appendix 4A provides background information on urban water pricing.

Urban Water Conservation Actions. State and federal legislative actions have imposed standards to improve the water use efficiency of plumbing fixtures, by requiring that fixtures manufactured, sold, or installed after specified dates meet the targets shown in Table 4-3. These requirements apply to new construction or to retrofitting existing plumbing fixtures, but do not require removal and replacement of existing fixtures. One water conservation action being taken by urban water agencies is to sponsor programs for voluntary retrofitting of fixtures, to accelerate resulting demand reductions. (This action is one of the BMPs included in the MOU described below.)

Table 4-3. Summary of California and Federal Plumbing Fixture Requirements

Plumbing Device	*California (covers sale and installation)*	*Effective Date*	*Federal Energy Policy Act of 1992 (covers only manufacture)*
Showerheads	2.5 gpm	CA: 3-20-92 US: 1-1-94	2.5 gpm
Lavatory Faucets[1]	2.75 gpm 2.2 gpm	CA: 12-22-78 CA: 3-20-92 US: 1-1-94	2.5 gpm
Sink Faucets[1]	2.2 gpm	CA: 3-20-92 US: 1-1-94	2.5 gpm
Metering (self-closing) Faucets[2] (public restrooms)	hot water maximum flow rates range from 0.25 to 0.75 gallons/ cycle and/or from 0.5 gpm to 2.5 gpm, depending on controls and hot water system	CA: 7-1-92 US: 1-1-94	0.25 gallons/cycle (pertains to maximum water delivery per cycle)
Tub Spout Diverter[1]	0.1 (new), to 0.3 gpm (after 15,000 cycles of diverting)	CA: 3-20-92	(does not appear to be included in FEPA)
Water Closets (residential)	1.6 gpf	CA: 1-1-92 (new construction) CA: 1-1-94 (all toilets for sale or installation) US: 1-1-94 (non-commercial)	1.6 gpf
Flushometer valves[1]	1.6 gpf	CA: 1-1-92 (new construction) CA: 1-1-94 (all toilets) US: 1-1-94 (commercial) US: 1-1-97 (commercial)	3.5 gpf 1.6 gpf
Water Closets ("For Commercial Use")[1]	1.6 gpf	CA: 1-1-94 (all toilets for sale or installation) US: 1-1-97	1.6 gpf
Urinals	1.0 gpf	CA: 1-1-92 (new) CA: 1-1-94 (all) US: 1-1-94	1.0 gpf

1 Indicates that California requirements are preexisting and more stringent than federal law; therefore California requirement prevail in California.

2 Indicates that federal law is more stringent than California requirements.

More than 200 urban water suppliers have signed the 1991 Memorandum of Understanding for Urban Water Conservation (described in Chapter 2) and are now members of the California Urban Water Conservation Council. (CUWCC membership also includes environmental organizations and other interest groups.) Water suppliers signing the urban MOU are committed to implementing BMPs unless a cost-benefit analysis conducted according to CUWCC guidelines showed individual BMPs not to be cost-effective or there is a legal barrier. The MOU also commits CUWCC to studying measures that could potentially be added as additional BMPs, such as establishing efficiency standards for water-using appliances.

Landscape Water Use

The Model Water Efficient Landscape Ordinance was added to Title 23 of the California Code of Regulations in response to requirements of the 1990 Water Conservation in Landscaping Act. Local agencies that did not adopt their own such ordinances by January 1993 were required to begin enforcement of the model ordinance as of that date.

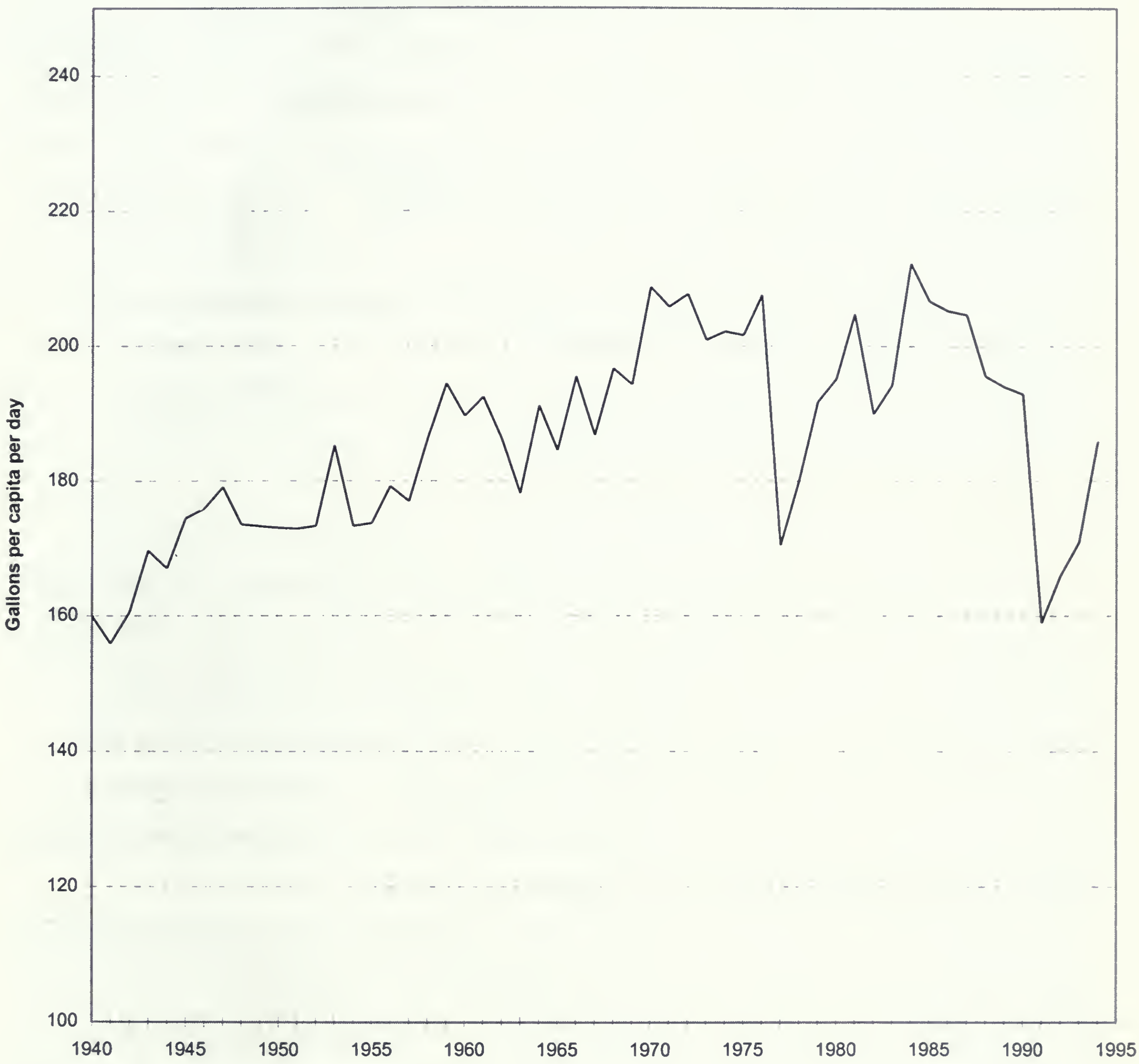
The model ordinance applies to all new and rehabilitated landscaping (more than 2,500 square feet in size) for public agency projects and private development projects that require a local agency permit, and to developer-installed landscaping for single-family and multi-family residential projects. The purpose of the ordinance was to promote water efficient landscape design, installation, and maintenance. The general approach of the ordinance is to use 0.8 ET_0 as a water use goal for new and renovated landscapes. Tools to help meet that goal include proper landscape and irrigation system design.

Efforts to quantify demand reduction from implementation of some of the BMPs have been difficult (e.g., quantifying the results of public information programs and water education in schools. These actions contribute to implementation of other BMPs, such as plumbing retrofits, but do not by themselves save water). CUWCC reviewed implementation and quantification of the current BMPs, and developed a strategic plan in 1996 whose elements included evaluating the BMPs and revising them as necessary to make them easier to quantify. The revised BMPs (see sidebar) were adopted by CUWCC in September 1997. The revisions included restructuring the original 16 BMPs to 13 BMPs (two new BMPs were added -- rebate programs for high efficiency washing machines and wholesale water agency assistance to retail water agencies), revising implementation schedules and coverage requirements, and adding new evaluation criteria. The implementation of some BMPs was extended beyond the original 10-year term of the existing MOU. Appendix 4B presents a synopsis of the revisions.

For the purpose of making Bulletin urban per capita use forecasts, the Department assumes that the BMPs will be implemented by 2020, as described in the following section on forecasting. BMP implementation is estimated to result in a 2020 demand reduction of 1.5 maf statewide. As discussed in Chapter 6, this demand reduction is not the same as creating new water supply. Only conservation actions that reduce irrecoverable losses (such as water discharged to the ocean or to saline perched groundwater) actually create new water supply from a statewide standpoint. We assume that BMPs will be implemented statewide because of their other potential benefits to local agencies, such as reduced costs for municipal water and wastewater treatment.

Effects of Droughts on Water Use. After the severe, but brief, 1976-77 drought, statewide water use data showed that urban per capita water use rates returned to their pre-drought levels within 3-4 years. During the longer 1987-92 drought, urban per capita water use rates declined by about 19 percent on the average statewide. The Department's data show increases in per capita water use following that drought, due to removal of mandatory water rationing and other short-term restrictions. In 1995, statewide per-capita urban water use remained about 8 percent below pre-drought levels. Figure 4-5 shows changes in statewide per capita use over time. At a local level, there may be factors other than drought contributing to this decline in per capita use, but when viewed at a statewide level the data show a strong response to hydrologic conditions. (As shown in Table 4-3, most of the new requirements for water-conserving plumbing fixtures did not take effect until after the last drought.)

Figure 4-5. Changes in Urban Per Capita Water Use Over Time



Urban Best Management Practices (1997 Revision)

BMP #1, Water Audits Programs for single-family and multi-family residential customers
BMP #2, Residential Plumbing Retrofit
BMP #3, Distribution System Water Audits, Leak Detection and Repair
BMP #4, Metering With Commodity Rates
BMP #5, Large Landscape Conservation Programs and Incentives
BMP #6, High-Efficiency Washing Machine Rebate Programs
BMP #7, Public Information Programs
BMP #8, School Education Programs
BMP #9, Conservation Programs for Commercial, Industrial, and Institutional Accounts
BMP #10, Wholesale Agency Assistance Programs
BMP #11, Conservation Pricing
BMP #12, Conservation Coordinator
BMP #13, Residential ULFT Replacement Programs

Urban Water Use Planning Activities

The Department has surveyed retail water agencies and analyzed their water production data for more than 35 years, and has published the data in our Bulletin 166 series, Urban Water Use in California. Bulletin 166-4, published in 1994, summarized monthly urban water production data for nearly 300 retail water purveyors (distributed throughout the State's ten major hydrologic regions) from 1980-1990. This water use information, updated in annual surveys performed by the Department, forms the basis for water use estimates made for Bulletin 160. The next update of Bulletin 166 will publish post-1990 data.

The Urban Water Management Planning Act requires urban water suppliers with 3,000 or more connections, or that deliver over 3,000 af of water per year, to prepare urban water management plans and to submit them to the Department. The initial set of plans was due in 1985, and the plans are to be updated every five years. Table 4-4 shows the number of agencies affected by the law, and those that had submitted their 1995 plans as of March 1997. The 1995 plans received were from agencies representing almost 90 percent of all urban water deliveries. These plans have multiple purposes, including demonstrating how local agencies propose to implement water conservation measures and how the agencies plan to meet water supply reliability goals in drought years.

Table 4-4. 1995 Urban Water Management Plans

Hydrologic Region	*Plans Expected*	*Plans Filed*
North Coast	13	10
San Francisco Bay	60	46
Central Coast	28	17
South Coast	187	152
Sacramento River	35	33
San Joaquin River	29	12
Tulare Lake	22	13
North Lahontan	5	2
South Lahontan	12	11
Colorado River	13	6
Total	**404**	**302**

The CALFED Bay-Delta program is including water use efficiency -- in the urban, agricultural, and environmental sectors -- as one of the common elements required for all its proposed Delta alternatives. Major elements of a potential urban water use efficiency program now under discussion could include:

(1) Requirements that urban water management plans be implemented more vigorously and that the Department should review and certify those plans.

(2) Revisions to the BMPs to make them more quantifiable.

(3) Requirements that CUWCC certify BMP implementation.

CALFED is also examining assurances that the urban water use efficiency program will be implemented vigorously. For example, urban water agencies that choose not to implement the program could be excluded from CALFED water transfers, from new supplies made available by CALFED actions, or from participating in certain loan and grant programs. In addition, CALFED has suggested that SWRCB could be asked to pursue its obligations to investigate waste and unreasonable use more vigorously.

Variation in Conservation Estimates -- Bulletin 160 and CALFED

This update of the California Water Plan presents the Department's estimates of reductions in water demand that may occur from the implementation of urban and agricultural water conservation. The CALFED Bay-Delta Program will also develop estimates of future reductions in water demand. The estimates prepared by the Department and CALFED will not be identical, because they are prepared for different planning purposes and they examine different future scenarios.

Bulletin 160-98 is a framework for making water resources decisions. Base case estimates of future conservation savings are prudently conservative (limited to implementation of urban BMPs and agricultural EWMPs) so that the future gap between supply and demand is not underestimated. Additional options for potential future conservation savings, which may be more difficult to achieve, are also presented.

CALFED will propose a comprehensive, long-term solution to interrelated resource problems of the Bay-Delta, including water supply reliability. Estimates of conservation savings under the CALFED "no-action" and "with-project" alternatives are being prepared. The no-action estimate will be similar to the base case described in Bulletin 160-98, but will describe more demand management than the more conservative Bulletin 160-98 estimate. The CALFED with-project estimate will be comparable to the options in the Bulletin, but will include more demand management water savings. This will reflect the sharp increases in funding and regulatory support that CALFED will propose for demand management programs.

Urban Water Use Forecasting

Urban water use forecasting techniques relate future water use to expected changes in factors known to influence water use. Early forecasting methods were relatively simple and relied only on service area population to explain water use, assuming a direct relationship between population growth and applied water demand. Such methods can provide acceptable results over the short term, especially during periods of abundant water supply and steady economic growth. However, mid- to long-term forecast accuracy may decrease sharply due to changes in other variables that influence water use. Among these determining factors are changes in the ratio of single to multifamily dwellings, climate, commercial and industrial growth, income, future water conservation actions, and water pricing. (Although the price of water currently plays a small role in water use, it could become more important if water prices increase significantly. The urban water price elasticity section in Appendix 4A provides more detail on this subject.) New urban water supplies will be relatively expensive, so understanding the interactions between price and water use is important for forecasting urban use.

The Department conducted an urban water use study for Bulletin 160-98 to forecast change in per capita water use by year 2020 in each hydrologic region. The results were used to estimate the 2020 urban applied water use by hydrologic region and statewide. The urban water use study relates future water use to expected change in population, income, economic activity, water price, and conservation measures (implementation of urban BMPs and changes to state and federal plumbing fixture standards). The relationships between water use and these variables were determined on the basis of local water agency data, economic forecasts, and literature review.

The general forecasting procedure for the urban water use study was to (1) determine 1995 base year per capita water use, (2) estimate the effects of conservation measures and socioeconomic change on future water use for 20 major representative water service areas in California, and (3) calculate 2020 per capita water use by hydrologic region using the results of the service area forecasts. Because of the regional scope of this study, the Department assumed a uniform implementation of BMPs in each service area. This assumption may not be consistent with the policies of the representative service areas.

1995 per capita water use. The 1995 level per capita water use was calculated for each of the Department's detailed analysis units. In the South Lahontan and Colorado River regions, analyses were done at the planning subarea level due to the relatively sparse population in those regions. The 1995 per capita water use is based on the 1990 level used in Bulletin 160-93, adjusted to account for permanent effects of urban BMPs and post-1990 changes to federal and state plumbing fixture standards. The most significant post-1990 change to the plumbing fixture standards was that all toilets for sale or installation in California must use no more than 1.6 gallons per flush, compared to 3.5 gallons or more per flush for older toilets. The 1995 per capita water use estimates also reflect broader data collection and evaluation efforts for various areas of the State.

Per capita water use forecast for 2020. Urban water use study forecasts were based on three types of input data: (1) Actual values of base-year water and socioeconomic variables, (2) forecasted values of socioeconomic variables for the year 2020, and (3) savings assumptions for each water conservation measure. Table 4-5 lists the menu of input variables specified for each water service area.

Table 4-5. Urban Water Use Study Input Variables

Water Use
Water use by sector, base year
Single family
Multi-family
Commercial
Industrial
Landscape
Seasonal water use, base year
Socioeconomic
Population, base-year and forecast-year
Total population
Population by dwelling type
Persons per household by dwelling type
Group quarters population
Housing, base-year and forecast-year
Number of housing units by dwelling type
Growth rate of housing stock by dwelling type
Employment, base-year and forecast-year
Commercial
Industrial
Income, base-year and forecast year
Water price, base-year and forecast year

Table 4-6. Urban Water Use Study Data Sources

Water Use
Survey of Public Water System Statistics, Department of Water Resources
Urban water management plans
Regional and local water agency reports on water use and conservation
Socioeconomic
Census of Population and Housing, U.S. Department of Commerce
Survey of Current Business, U.S. Department of Commerce
Statistical Abstract of the United States, U.S. Department of Commerce
California Statistical Abstract, Department of Finance
California Population Characteristics, Center for Continuing Study of the California Economy
Population Projects by Race and Ethnicity for California and its Counties 1990-2040, Department of Finance
Regional and local planning agencies

Historical urban water use data were from the Department's annual survey of public water system statistics and from urban water management plans prepared by local and regional water agencies. Base year socioeconomic data were obtained from a number of sources, including federal, state, regional, and local agencies. Socioeconomic forecasts were made by the Department based on studies done by the DOF, the U.S. Department of Commerce, regional government associations, and others. Table 4-6 lists the primary sources of water use and socioeconomic information used.

The urban water use study provided estimates of 2020 change in per capita water use in 20 representative water service areas within each of the State's ten hydrologic regions (Table 4-7). (The results in this, and the following two tables, display changes from 1990, rather than from the 1995 base year used for B160-98, to illustrate all of the effects of water conservation implementation, including the changes in plumbing fixture standards in the early 1990s.) The results of the 20 individual model runs were extrapolated to estimate 2020 level per capita water use by hydrologic region (Tables 4-8 and 4-9). The forecast projects that statewide per capita water use will decline by about 10 percent by 2020. The difference between the 1995 and 2020 levels reflect the influence of water conservation measures and socioeconomic change on per capita water use in each region. Per capita use level for 1990 is shown in these tables for comparison.

The study results were used to estimate year 2020 urban applied water. The projected change in per capita water use in each region, expressed as a percentage, was applied to the 1995 level per-capita water use for each DAU to estimate the 2020 level per capita water use. The 2020 level per-capita water use then was multiplied by the population forecast to compute 2020 urban applied water use for each DAU. These results were aggregated to compute the 2020 level urban applied water use by hydrologic region and statewide.

Table 4-7. Per Capita Water Use With Economic Growth and Conservation Measures

		1990	2020	2020	2020
		Base	Economic Effects	Conservation Effects	Forecast
Hydrologic Region	Representative Water Service Area	GPCD	% Change From 1990	% Change From 1990	GPCD
North Coast	City of Santa Rosa	156	2%	14%	136
San Francisco	EBMUD	196	3%	16%	171
	Marin Municipal Water District	153	5%	16%	136
	City and county of San Francisco	132	3%	16%	115
Central Coast	California Water Service Company, Salinas	153	0%	14%	132
	City of Santa Barbara	177	4%	15%	156
South Coast	City of Los Angeles	180	4%	16%	158
	City of San Bernardino	269	1%	11%	243
	San Diego County Water Authority	196	4%	14%	176
Sacramento River	California Water Service Company, Chico	296	2%	10%	272
	City of Sacramento	290	3%	13%	263
San Joaquin River	California Water Service Company, Stockton	187	1%	12%	162
	City of Merced	336	0%	-10%	299
Tulare Lake	California Water Service Company, Visalia	273	3%	-11%	235
	City of Fresno	285	2%	-10%	262
North Lahontan	South Lake Tahoe PUD	179	2%	15%	147
South Lahontan	Indian Wells Valley Water District	247	3%	10%	230
	Victor Valley County Water District	340	3%	8%	322
Colorado River	City of Blythe	349	4%	11%	326
	City of El Centro	221	2%	13%	197

Table 4-8. Per Capita Water Use[1] by Hydrologic Region, 1995 and 2020 (in gallons per capita per day)

Region	1990 Base	1995 Base	2020 Forecast without conservation	2020 Forecast with conservation
North Coast	263	255	267	229
San Francisco Bay	193	177	199	169
Central Coast	189	180	192	164
South Coast	211	208	222	192
Sacramento River	283	274	292	257
San Joaquin River	309	301	306	269
Tulare Lake	301	311	304	274
North Lahontan	421	409	411	347
South Lahontan	278	284	287	262
Colorado River	579	578	594	522
Statewide	**230**	**224**	**237**	**203**

[1] Includes residential, commercial, industrial, and landscape use

Table 4-9. Percent Change in Per Capita Use by Hydrologic Region

Region	Economic Effects % Change from 1990	Conservation Efforts % Change from 1990
North Coast	2%	-14%
San Francisco Bay	3%	-16%
Central Coast	2%	-15%
Sacramento River	3%	-12%
San Joaquin River	-1%	-12%
Tulare Lake	1%	-10%
North Lahontan	-2%	-15%
South Lahontan	3%	-9%
Colorado River	3%	-12%
Statewide	**3%**	**-15%**

Summary -- Urban Water Demands

Table 4-10 shows the summary of Bulletin 160-98 urban water demands by hydrologic region. Statewide urban demands at the 1995 base level are 8.8 maf in average water years, and 9.0 maf in drought years. (Drought year demands are slightly higher because less precipitation is available to meet exterior urban water uses, such as landscape watering.) Projected 2020 demands increase to 12.0 maf in average years and 12.4 maf in drought years. Full implementation of urban BMPs is estimated to result in demand reduction of 1.5 maf in average year water use by 2020. Without implementation of urban BMPs, average years demands would have increased to 13.5 maf.

As indicated in the table, the South Coast and San Francisco Bay hydrologic regions together amount to about 64 percent of the State's total urban demands.

Table 4-10. Urban Applied Water Use by Region
(taf)

	1995		*2020*	
Region	***Average***	***Drought***	***Average***	***Drought***
North Coast	169	177	201	212
San Francisco Bay	1,255	1,358	1,317	1,428
Central Coast	286	294	379	391
South Coast	4,340	4,382	5,519	5,612
Sacramento River	766	830	1,139	1,236
San Joaquin River	574	583	954	970
Tulare Lake	690	690	1,099	1,099
North Lahontan	39	40	50	51
South Lahontan	238	238	619	619
Colorado River	418	418	740	740
Total	**8,773**	**9,009**	**12,017**	**12,356**

Water Use Impacts from Conversion of Agricultural Land Use to Urban Land Use for a San Joaquin Valley Example

As discussed in the agricultural water use section of this chapter, the Department is projecting a decline in California's irrigated acreage in 2020, due in part to urbanization of agricultural lands. Much of this urbanization will occur in the South Coast region and in the San Joaquin Valley. This sidebar reviews potential changes in water use resulting from land use conversion, changes that are often of concern to local agencies responsible for land use planning or for provision of water supplies. Changes in water use must be evaluated on a site specific basis, as the following example for the San Joaquin Valley illustrates.

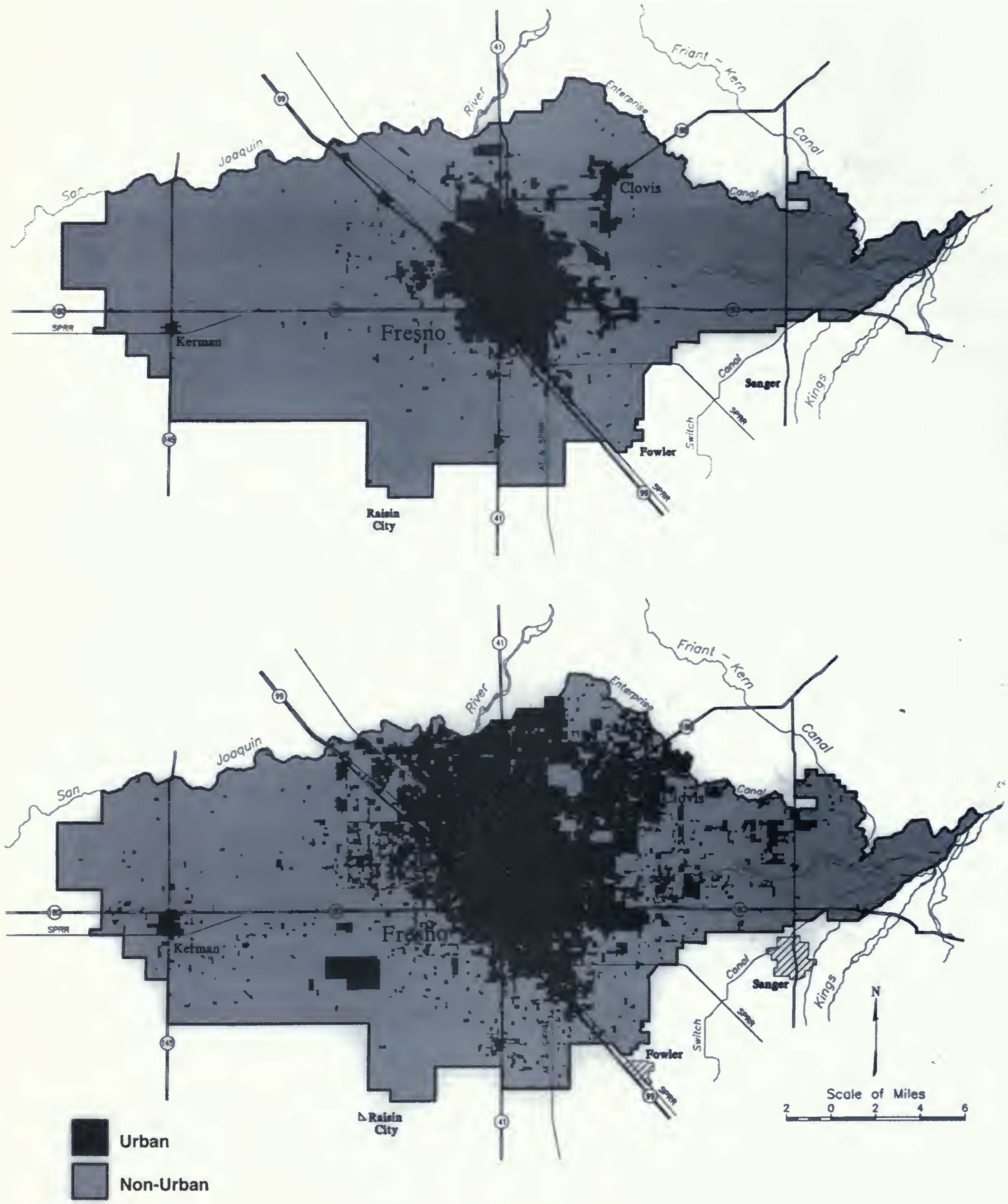
Changes in water use due to land use changes depend on the kinds of crops grown and the density and type of urban development in a particular area. In the case of single-family dwellings, for example, applied water use varies with housing density. Numerous studies have shown that dwellings on larger lots use more water per dwelling unit due to the larger landscaped area. However, higher density developments (those with smaller lots) have the greater applied water per acre of land. A recent Department study revealed that, for a particular area (the Department's DAU 233), the applied water use of single-family dwellings and agricultural crops are often similar at low housing densities (four or five units per acre). However, higher density developments of single-family dwellings (six units or more per acre) that have become common in today's new home construction market tend to have greater applied water requirements than many crops.

Growth in the Fresno area of the central San Joaquin Valley has caused expansion of urban development onto adjoining agricultural lands. Figure 4-6 is a plot of Department land use data that illustrates the long-term expansion of urban development onto agricultural lands in this area. Department data show that urban applied water use in the Fresno area, including that used for residential, commercial, and industrial purposes, is equivalent to about 3.2 acre-feet per acre. By comparison, agricultural applied water for the various crops grown in the area ranges from about 1 acre foot per acre (grain) to about 4.7 acre-feet per acre (alfalfa), as shown in the comparison below for urban applied water use with the main crops grown in the area. They are, in order of planted acreage, grape vines, deciduous orchards, pasture (alfalfa and improve pasture), and cotton.

Type of Use	*Applied Water Use (af/acre)*
Urban	3.2
Agricultural	
Grapevines	2.9
Deciduous orchard	3.5
Alfalfa	4.7
Pasture (improved)	4.5
Cotton	3.2

Other factors to consider when evaluating water use impacts associated with land use conversion include water supply depletion and water quality. For example, a water supply suitable for irrigating some crops may not be suitable for a purpose needing higher water quality, such as a potable water supply.

Figure 4-6. Changes in Land Use Over Time, DAU 233



Agricultural Water Use

In simplest terms, the Department's estimates of agricultural water use are derived by multiplying water use requirements for different crop types by their corresponding statewide irrigated acreage, and summing the results to obtain a total for irrigated crops in the State. The details of estimating crop water use and irrigated acreage, however, are far from simple. This section begins by covering crop water use requirements, including demand reduction achievable through implementing water conservation programs. The concepts of irrigation efficiencies and distribution uniformity are discussed in some detail. We then describe the Department's process for forecasting future irrigated acreage, and factors such as agricultural drainage problems that affect acreage forecasts. A summary of 2020 agricultural water demands is provided at the end of the section.

Crop Water Use

The water requirement of a crop is directly related to the water lost through evapotranspiration. The amount of water that can be consumed through ET depends in the short term on local weather and, in the long term, on climate. Energy from solar radiation is the primary factor that determines the rate of crop ET. Also important are humidity, temperature, wind, stage of crop growth, and the size and aerodynamic roughness of the crop canopy. Irrigation frequency can affect ET after planting and during early growth, because evaporation increases when the soil surface is wet and exposed to sunlight. Generally, ET remains independent of soil moisture content; however, as the soil dries and soil moisture tension approaches a plant's permanent wilting point, the flow of water into plant roots can fall below the rate needed to meet crop water needs. Growing season ET varies significantly among crop types, depending primarily on how long the crop actively grows.

The amount of water applied to a given field for crop production is based on considerations such as crop water requirements, soil characteristics, the ability of an irrigation system to distribute water uniformly on a given field, and irrigation management practices. In addition to ET, other crop water requirements can include water needed to leach soluble salts below the crop root zone, and water that must be applied for frost protection or cooling. The amount required for these uses depends upon the crop, irrigation water quality, and weather conditions.

Part of a crop's water requirements can be met by rainfall. The amount of rainfall beneficially used for crop production is called effective rainfall. Effective rainfall is stored in the soil and is available to satisfy crop evapotranspiration or to offset water needed for special cultural practices such as leaching of salts. The remainder of the crop water requirement must be provided through irrigation. Irrigation efficiency influences the amount of applied water needed, since a portion of each irrigation goes to system leaks and deep percolation of irrigation water below the crop root zone.

Figure 4-7. Ranges of Applied Water and Evapotranspiration of Applied Water

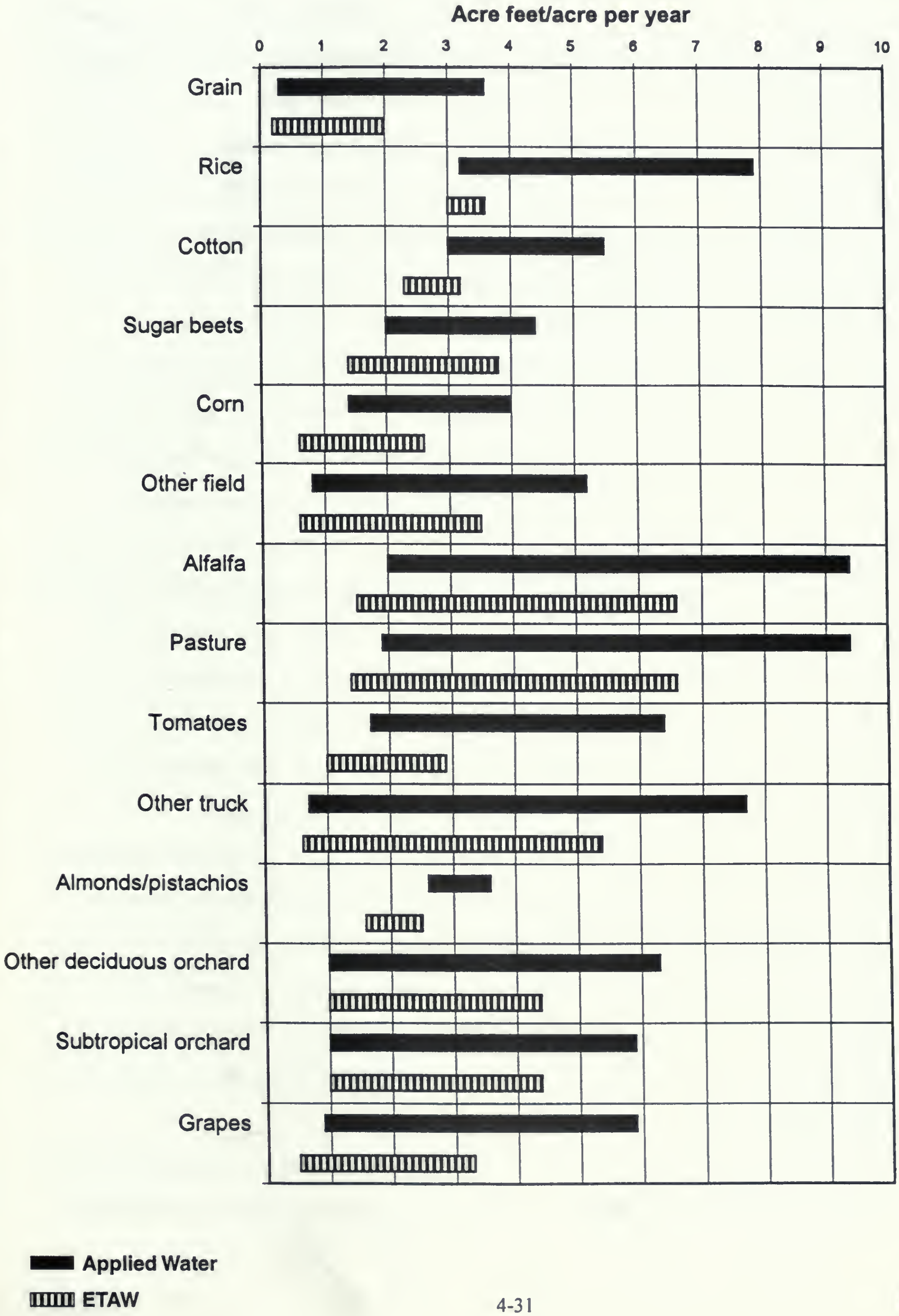


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Figure 4-7 shows ranges of applied water and evapotranspiration of applied water for some common California crops or crop types. (ETAW is the portion of crop ET which is supplied by irrigation.) ETAW represents a major depletion of water supply, and therefore is an important component of statewide and local water supply planning, groundwater modeling, and water transfer feasibility studies.

The range in the values for the crops shown is due to geographic variations in factors such as farming practices, soils, climate, and water availability and cost. Except in areas adjacent to the ocean, or areas where the groundwater or surface water is unacceptable for reuse, irrigation water applied in excess of ET and cultural requirements (e.g., frost protection) is available to downstream users, or to others pumping from groundwater.

Direct measurement of crop ET requires costly investments in time and in sophisticated equipment. There are more than 9 million acres of irrigated crop land in California, encompassing a wide range of climate, soils, and crops. Even where annual evapotranspiration for two areas is similar, monthly totals may be significantly different. For example, average annual evapotranspiration for interior valleys of the central coast is similar to that of the Central Valley; however, Central Valley ET is lower than that in the coastal valleys during the winter fog season, and higher during the clear, hot summer weather. Obtaining actual measurements for every combination of environmental variables would be prohibitively difficult and expensive. A more practical approach is to estimate ET using methods based on correlation of measured ET with observed evaporation, temperature, and other climatologic conditions. Such methods can be used to transfer the results of measured ET to other areas with similar climates.

The Department uses the ET/Evaporation correlation method to estimate growing season ET. Concurrent with field measurement of ET rates, the Department developed a network of agroclimate stations to determine the relationship between measured ET rates and pan evaporation. Data from agroclimatic studies reveal that water evaporation from a standard water surface (the Department uses the US Weather Bureau Class A evaporation pan) closely correlates to crop evapotranspiration. The ET/Evaporation method has estimated crop water use to within +/- 10 percent of measured seasonal ET.

Crop coefficients are applied to pan evaporation data to estimate evapotranspiration rates for specific crops. Crop coefficients vary by crop, stage of crop growth, planting and harvest dates, and growing season duration. The resulting data, combined with information on effective rainfall, form the basis for calculating ETAW and applied water demands.

Factors Influencing Crop Water Use

Agricultural Water Conservation Programs. Negotiations over a Memorandum of Understanding Regarding Efficient Water Management Practices by Agricultural Water Suppliers in California were completed in 1996, and the MOU has been circulated for signatures. The Agricultural Water Management Council called for in the MOU to oversee endorsement of agricultural water management plans has begun meeting. As of November 1997, 29 agricultural water agencies serving about 2.8 million acres of land had signed the MOU. Signatories to the MOU have committed to implement specified EWMPs, based on their evaluation of the benefits of each practice. These EWMPs are listed below as shown in the MOU.

Efficient Water Management Practices for Agricultural Water Suppliers in California

List A--Generally Applicable EWMPS:

- Prepare and adopt a water management plan
- Designate a water conservation coordinator
- Support the availability of water management services to water users
- Improve communication and cooperation among water suppliers, water users, and other agencies
- Evaluate the need, if any, for changes in institutional policies to which the water supplier is subject
- Evaluate and improve efficiencies of the water supplier's pumps

List B--Conditionally Applicable EWMPs:

- Facilitate alternative land use
- Facilitate using available recycled water that otherwise would not be used beneficially, meets all health and safety criteria, and does not cause harm to crops or soil
- Facilitate financing capital improvements for on-farm irrigation systems
- Facilitate voluntary water transfers that do not unreasonably affect the water user, water supplier, the environment, or third parties
- Line or pipe ditches and canals
- Increase flexibility in water ordering by, and delivery to, the water users within operational limits
- Construct and operate water supplier spill and tailwater recovery systems
- Optimize conjunctive use of surface and groundwater
- Automate canal structures

List C--Other EWMPs:

- Water measurement and water use report
- Pricing or other incentives

These EWMPs can lessen runoff and deep percolation of irrigation water, reducing the amount of water farmers must order from an irrigation district or pump from their wells. Table 4-11 shows that agricultural water conservation is expected to reduce applied water demands by about 800 taf annually by 2020. These reductions will come about through use of the EWMPs to improve the efficiency of irrigation water application over the growing season (discussed in the following section). Such reductions of applied water generally do not create new water supply; in most areas of California, excess irrigation water becomes available to other users. Even so, a reduction in applied water can serve other beneficial purposes such as reducing leaching of plant nutrients, reducing degradation of groundwater quality, and reducing agricultural drainage.

Only practices that lessen evaporation from water surfaces, reduce evapotranspiration, or diminish unrecoverable losses to saline water actually reduce depletions to water supply.

Efficient water management practices have relatively little effect on evaporation and ET. Therefore, it is the location of water use, rather than the conservation measure employed, that is key to determining whether a reduction in irrigation water use translates into a depletion reduction. Agricultural lands adjacent to the ocean, or where the groundwater or surface water is unacceptable for reuse have the greatest potential for reducing depletions through efficient water management practices. In California, such agricultural lands are found in the south coast, the west side of the San Joaquin Valley, and the southeastern desert. Expected annual depletion reductions by 2020 are illustrated in Table 4-11.

Table 4-11. Annual Reductions in Applied Water and Depletions Due to EWMP Implementation by 2020 (taf)

Hydrologic Region	*Applied Water Reductions*	*Depletion Reductions*
North Coast	1	0
San Francisco Bay	1	0
Central Coast	82	0
South Coast	31	10
Sacramento River	203	0
San Joaquin River	148	1.7
Tulare Lake	45	0.6
North Lahontan	17	0
South Lahontan	20	10
Colorado River	249	210
Total	**797**	**232**

Irrigation Efficiencies. Relationships between on-farm and regional efficiencies are complex. Often a portion of irrigation water applied to a field runs off the field or percolates into the groundwater. Runoff and/or deep percolation from a given field may be considered a water loss to that particular field; nevertheless, often this water is not a loss to the system. Where water quality is good, this water may be reused on that field or on other fields several times. Irrigation efficiency formulas developed for on-farm irrigation management cannot necessarily be applied to larger areas or regions. Numerical values of on-farm and regional efficiencies almost always differ. On-farm efficiencies are usually lower than regional efficiencies due to reuse of water in a region.

On-farm irrigation efficiency equations do not consider water reuse from one farm to another. The implicit assumption is that fields, farms, and regions are hydrologically disconnected. In reality, this is seldom the case. Water loss from a field is not a water loss to the region, except where runoff goes directly to a nonreusable water source such as saline groundwater or the ocean. With reuse, regional efficiencies are higher than those of on-farm efficiencies. A region can reach very high efficiencies as a result of a few reuses, even if on-farm efficiencies remain fairly low. Practices that help reuse of water, such as tail water return and spill recovery systems, provide an opportunity to increase regional efficiency. Water reuse can be the fastest and most economical way to boost regional efficiencies.

Distribution uniformity in an important element in achieving higher on-farm irrigation efficiencies. Distribution uniformity is defined as a measure of the variation in the amount of water applied to the soil surface throughout the irrigated area. Since no irrigation system is capable of applying and distributing water evenly and uniformly to all parts of a field, growers often apply enough water to meet crop water requirements of the driest part of the field to achieve optimum crop yields. Achieving a high DU requires excellent system design, maintenance, and management. Irrigation experts maintain that current hardware design and manufacturing technology limit the DU of most systems to 80 percent. As design and manufacturing technology advance and more refined manufacturing processes and hardware are developed it may then be possible to achieve irrigation efficiencies up to 90 percent.

Forecasts of agricultural demand are based in part on assumptions about future trends in seasonal application efficiency, a measure of the efficiency of irrigation water use over the growing season. Seasonal application efficiency is defined as the water beneficially used for ETAW and cultural practices divided by applied water. It is assumed that by 2020 seasonal application efficiency will reach 73 percent in all regions of California, averaged across crop types, farm land characteristics, and management practices. The distribution uniformity of irrigation methods is limiting to SAE. The average DU of irrigation systems in California is currently in the 70 to 75 percent range, based on numerous irrigation system evaluations conducted by the Department, resource conservation districts, water districts, and others. It is envisioned that by 2020, the average DU will be about 80 percent. An irrigation method with a DU of 80 percent can achieve a maximum SAE of about 73 percent, assuming that irrigation events are properly timed, the soil is well drained, and none of the field is under-irrigated. The annual water savings expected by 2020 that were shown in Table 4-11 are due to the expected increase in average SAE to 73 percent.

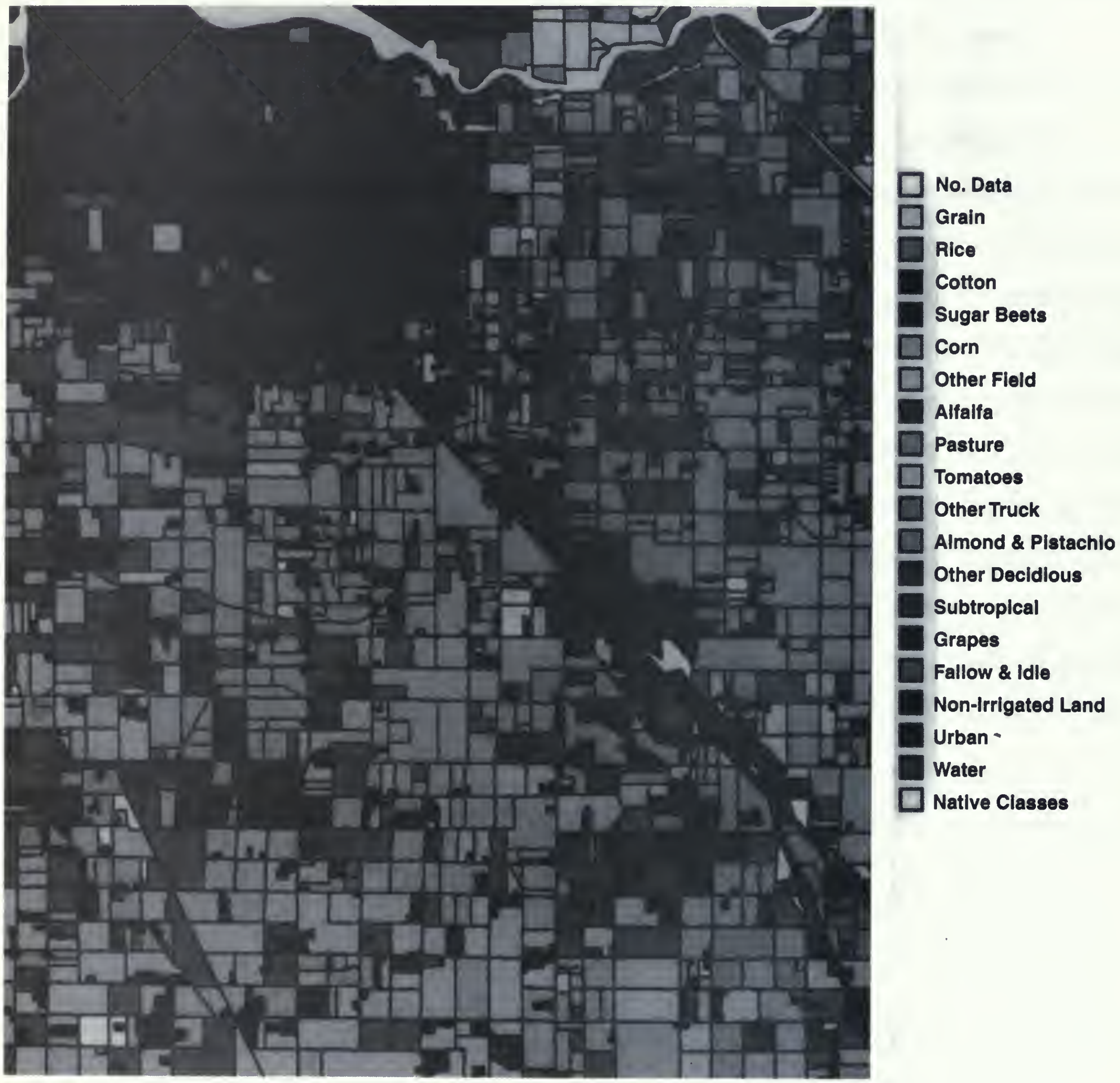
Agricultural Acreage Forecasting

This section describes how 1995 base year irrigated acreage is established, and how that information is used to forecast 2020 irrigated acreage.

Quantifying Present Irrigated Acreage. Forecasts of future agricultural acreage start with land use data that characterize existing crop acreages. The Department has been performing land use surveys since the 1950s to quantify acreage of irrigated land and corresponding crop types, and currently maps irrigated acreage in six to seven counties per year. Counties with significant amounts of irrigated land are normally surveyed at least once per decade, and the results of the surveys are published as county land use reports.

The base data for the land use surveys is obtained from aerial photography or satellite imagery, which is superimposed on a cartographic base. Field boundaries are photo-interpreted on the base, and digitized. Site visits are used to identify or verify crop types growing in the fields. From this information, maps showing locations and acreage of crop types can be developed. Figure 4-8 is an example of a typical land use survey map, showing crop types in the Ceres 7.5 minute USGS quadrangle, from the Department's 1996 Stanislaus County survey.

Figure 4-8. Typical Land Use Map



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The Department's land use surveys focus on quantifying irrigated agricultural acreage. Thus, for example, fields of dry-farmed grains will be mapped in the land use surveys, but their acreage will not be tabulated for calculating water use. In some areas of the State, climate and market conditions are favorable for producing multiple crops per year on the same field (for example, winter vegetables followed by a summer cotton crop). For these cases, the annual irrigated acreage is counted as the sum of the acreage of the individual crop types for calculating water uses. In the years in between land use surveys of a particular county, the Department annually estimates crop types and acreage using data collected from county agricultural commissioners, local water agencies, University of California Cooperative Extension Programs, and the California Department of Food and Agriculture.

California's Nursery Industry

When people think of irrigated agriculture, crops that often come to mind are commodities such as hay, grains, rice, row crops, and cotton. However, based on 1996 California Department of Food and Agriculture statistics, nursery products (flowers, plants, turf-grass) rank as the State's third largest farm product in gross value, behind milk and cream, grapes, and cattle, ahead of cotton, almonds, and hay. The prominence of the nursery industry reflects the extent of urbanization in California, as well as favorable climatic conditions.

California nursery products had a $1.6 billion farmgate value (wholesale value at the farm) in 1996. San Diego is the leading California county in nursery product valuation, followed by Santa Barbara, San Mateo, and Los Angeles counties. California wholesale production represents about 26 percent of national sales.

An important difference between the nursery industry and other agricultural sectors is the extent to which the industry's revenues are tied to urban, as well as to agricultural, water supplies. Bulletin 160 treats nursery water use as an agricultural use. However, many of the industry's products are destined for urban and commercial locations where urban water supply availability and price influence landscaping choices, and hence the market, for some types of nursery products.

About 25,000 acres are devoted to nursery products in California. Much of the acreage is in proximity to urbanized, coastal regions of the State near markets and major transportation routes.

The starting point for determining Bulletin 160-98 1995 base acreage was normalized irrigated acreage for 1990 from Bulletin 160-93. Changes in crop acreage between 1990 and 1995 were evaluated to determine if they were due to short-term causes (e.g., drought or abnormal spring rainfall), or if there was an actual change in cropping patterns. The base year was developed to represent normalized crop acreage (the acreage that would most likely be expected in the absence of all weather and market related abnormalities). (More detail on the concept of normalizing base year data is presented in Chapter 3.) Figure 4-9 illustrates some general trends in California cropping patterns over time.

Crop acreage by region for the normalized 1995 base is presented in Table 4-12. The 1995 base irrigated land acreage is about 9.1 million acres, which, when multiple cropped areas are tabulated, becomes a base irrigated cropped acreage of about 9.5 million acres.

Figure 4-9. General Trends in Cropping Patterns Over Time

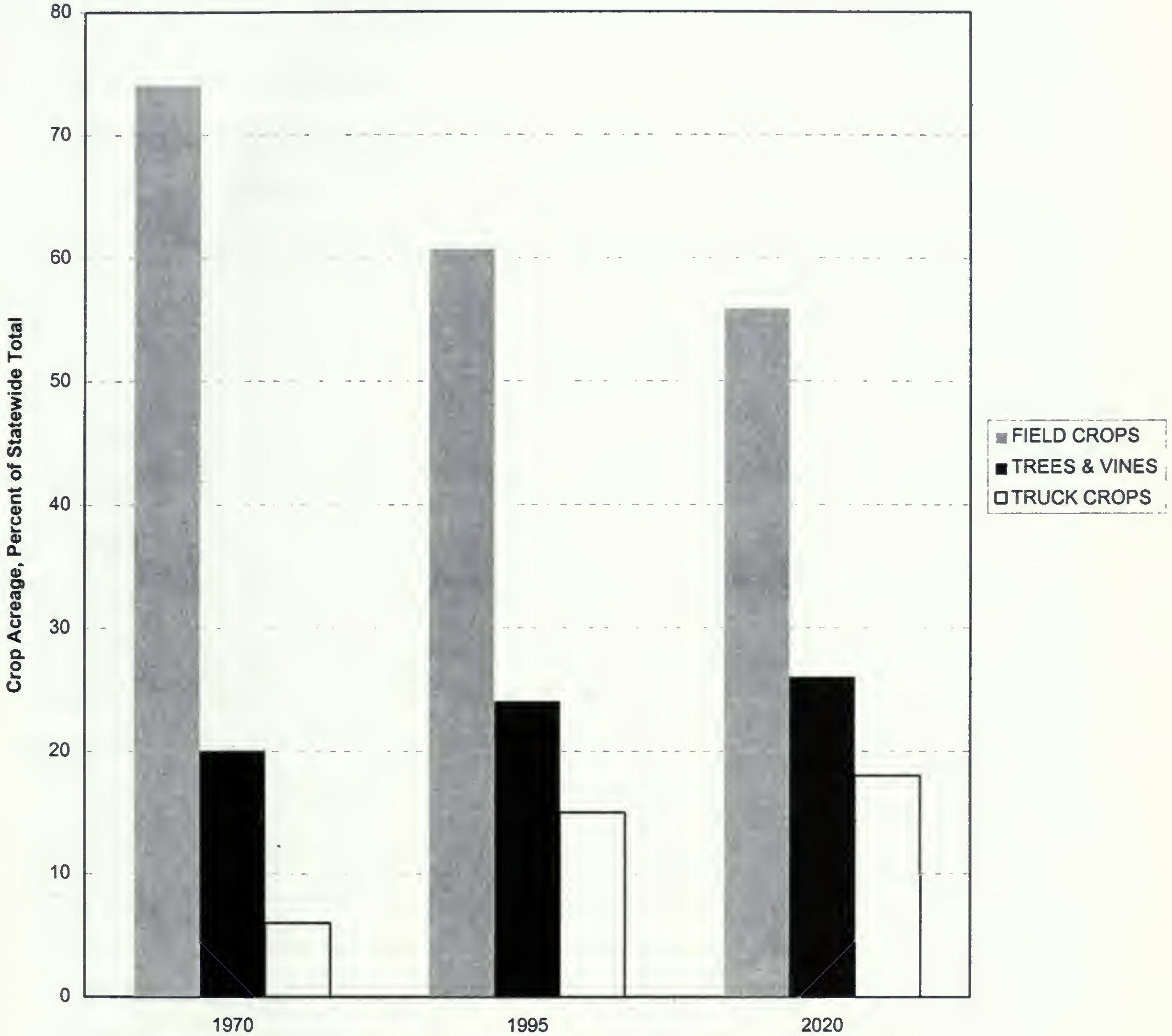


Table 4-12. 1995 Irrigated Acreage by Crop and Crop Type

California Crop and Irrigated Acreage by Hydrologic Region, 1995

(normalized, in thousands of acres)

Irrigated Crop	NC	SF	CC	SC	SR	SJ	TL	NL	SL	CR	TOTAL
Grain	72	2	26	11	270	180	260	7	2	70	900
Rice	0	0	0	0	494	22	0	1	0	0	517
Cotton	0	0	0	0	9	185	1,026	0	0	24	1,244
Sugar beets	6	0	3	0	54	47	30	0	0	38	178
Corn	1	1	3	4	92	212	116	0	0	9	438
Other field	3	1	16	4	155	120	97	0	1	70	467
Alfalfa	53	0	21	10	149	231	296	44	34	256	1,094
Pasture	122	5	18	20	352	199	49	107	18	43	933
Tomatoes	0	0	10	7	138	82	111	0	0	9	357
Other truck	23	11	382	87	56	130	194	2	3	172	1,060
Almond/pistachios	0	0	0	0	106	251	177	0	0	0	534
Other deciduous	7	6	18	3	219	154	191	0	3	1	602
Subtropical	0	0	19	161	28	8	202	0	0	37	455
Grapes	36	39	56	6	17	184	378	0	0	20	736
TOTAL Crop Area	323	65	572	313	2,139	2,005	3,127	161	61	749	9,515
Multiple Crop	0	0	142	30	52	56	63	0	0	104	447
Irrigated Land Area	323	65	430	283	2,087	1,949	3,064	161	61	645	9,068

Forecasting Future Irrigated Acreage. The Department's 2020 irrigated acreage forecast was developed using information from three tools: (1) staff research, (2) a Crop Market Outlook study, and (3) results from a Central Valley Production Model. As with any forecast of future conditions, there are uncertainties associated with each of these approaches. The Department's method of integrating the results of three independent approaches is intended to represent our best estimate of future acreage, absent major changes from present conditions. It is important to emphasize that many of the factors affecting future cropped acreage are based on national (federal Farm Bill programs) or international (world export markets) circumstances. California agricultural products compete with products from other regions in the global economy, and are affected by trade policies and market conditions that reach far beyond the State's boundaries.

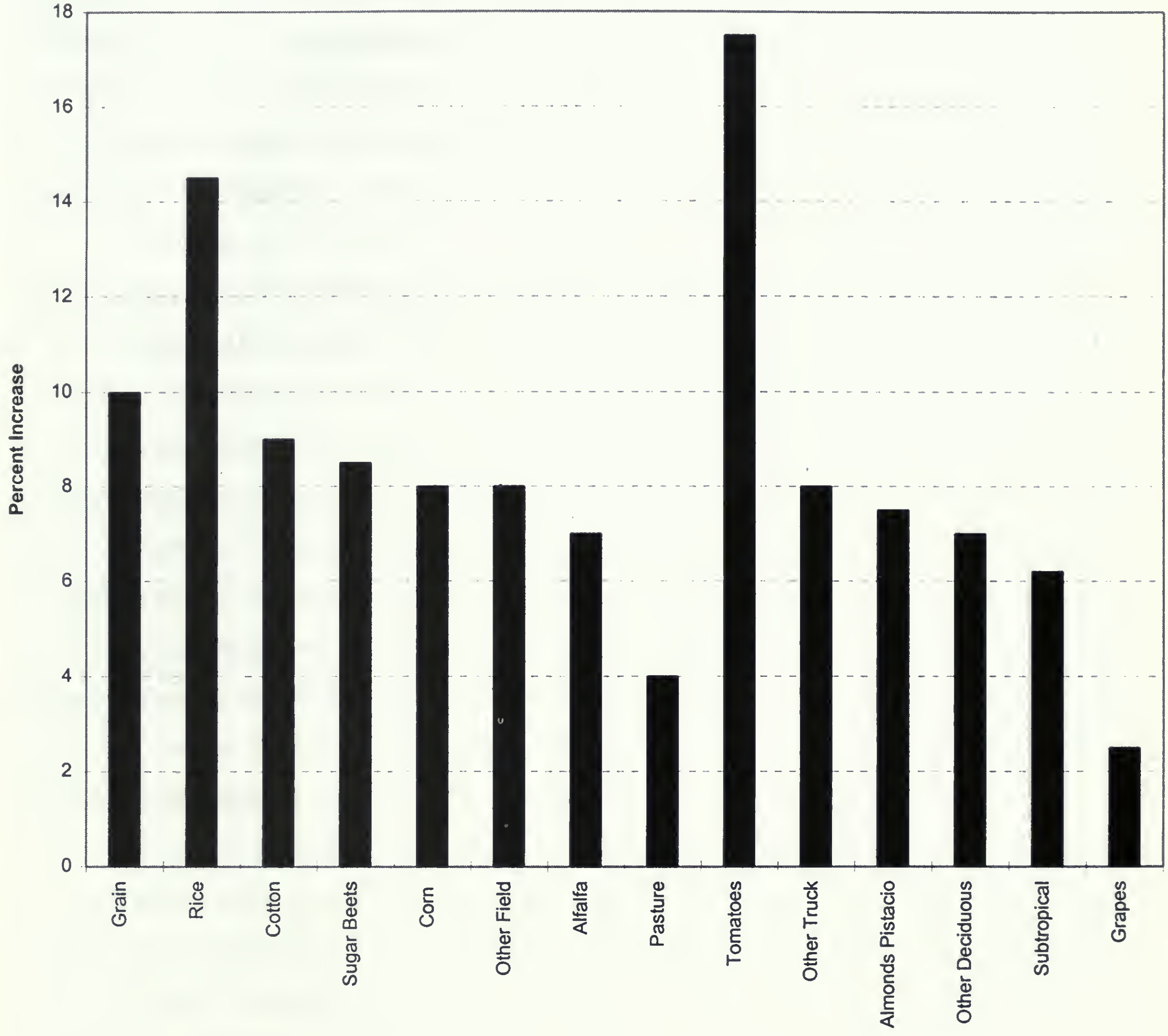
Intrastate factors considered in making acreage forecasts included urban encroachment onto agricultural land and land retirement due to drainage problems (discussed in more detail in the following section). Urbanization on lands presently used for irrigated agriculture is a significant consideration in the South Coast region and in the San Joaquin Valley, based on projected patterns of population growth. DOF 2020 population forecasts, along with information gathered from local agency land use plans, were used to identify irrigated lands most likely to be affected by urbanization. Local water agencies and county farm advisors were interviewed to assess their perspective on land use changes affecting agricultural acreage.

The Department's Crop Market Outlook, a form of Delphi analysis, was developed using information and expert opinions gathered from interviews with more than 130 University of California farm advisors, agricultural bankers, commodity marketing specialists, managers of cooperatives, and others. Three basic factors guided the CMO: (1) current and future demand for food and fiber by the world's consumers; (2) the share California could produce to meet this worldwide demand; and (3) technical factors, such as crop yields, pasture carrying capacities, and livestock feed conversion ratios that affect demand for agricultural products. (Milk and dairy products are California's largest agricultural product, in terms of gross value. The demand for these products is reflected in the markets for alfalfa and other fodder used by dairies.) The CMO forecasts a statewide crop mix and estimates corresponding irrigated acreage. The major findings of the CMO for year 2020 were that grain and field crop acreage would decrease, while the truck crops and permanent crops would increase.

The Central Valley Production Model is a mathematical programming model of Central

Valley farm production activities that simulates farming decisions by growers. Inputs include detailed information about production practices and costs as well as water availability and cost by source. The model also uses information on the relationship between production levels of individual crops and crop market prices. Figure 4-10 is an example of information used in the model, showing how crop yields are expected to increase. The model's geographic coverage is limited to the Central Valley, which represents about 80 percent of the State's irrigated agricultural acreage. The CVPM results also indicated future crop shifting, from crops with lower gross earning potentials (grains and field crops) to vegetables, trees, and vines. The CVPM forecast showed a small reduction in crop acreage from 1995 to 2020. The relative amounts of grain and field crops would drop, while the relative amount of truck crops and permanent crops (trees and vines) would increase.

Figure 4-10. Crop Yield Increases (1995 to 2020) Estimated by the Central Valley Production Model



Other Factors Affecting Forecasted Irrigated Acreage. The process of estimating future irrigated acreage described in the previous section considered statewide factors such as crop markets and urban expansion onto agricultural lands. The Department considered an additional region-specific factor, the long-standing agricultural drainage management issues on the west side of the San Joaquin Valley. Drainage management issues in this area have had a dual focus -- salt management to permit continued agricultural production on lands requiring drainage systems, and management of trace minerals (principally selenium) to limit adverse water quality and environmental impacts.

The need for drainage systems to permit farming in some westside areas was recognized concurrently with the development of irrigated agriculture in the region. USBR's San Luis Drain, for example, was originally planned to convey drainage water out of the valley to the San Francisco Bay. The drain was instead terminated at Kesterson Reservoir, where waterfowl mortalities lead to the discovery of elevated selenium levels in the early 1980s, and the drain was subsequently closed. (A discussion of the trial reopening of part of the drain for the Grasslands bypass channel project is provided in Chapter 8.) Post-Kesterson studies of valley drainage problems have sought to quantify factors such as extent of areas with shallow depths to ground-water, tributary areas in Coast Range sediments from which trace minerals are derived, and water quality characteristics of drain water and shallow groundwater.

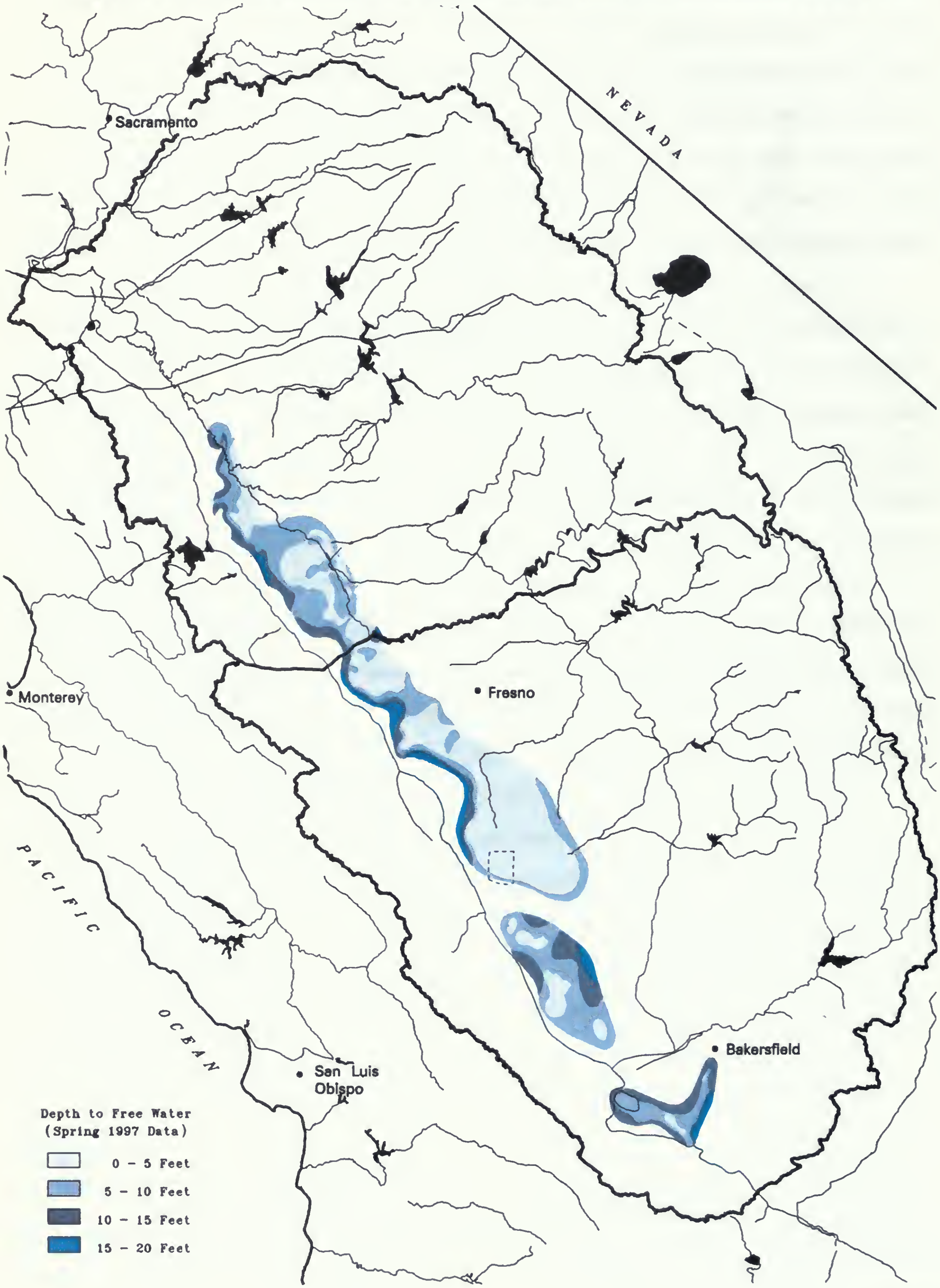
The 1990 report of the interagency San Joaquin Valley Drainage Program concluded that as much as 460,000 acres of irrigated land would be abandoned by the year 2020 unless a comprehensive approach to manage the drainage problem could be implemented before then. The report recommended retirement of 75,000 acres of land with the worst drainage problems by 2040. For the Bulletin 160-98 year 2020 acreage forecast, we have followed the same procedure used in Bulletin 160-93 and have assumed that the 75,000 acres would be retired at an average rate of 1,500 acres per year. Thus, 45,000 acres of land would be retired between 1990 and 2020. To put this amount into perspective, USBR's 1997 request for proposals for the CVPIA land retirement program (described in Chapter 6) elicited offers to sell 27,500 acres of drainage-impaired lands.

Figure 4-11 shows areas of shallow groundwater in the San Joaquin Valley, based on 1995 monitoring data. Monitoring of shallow groundwater in the drainage problem areas has indicated that slightly more than 1 million acres continue to have groundwater depths of less than

10 feet. Within this 1 million-acre area, the zone of groundwater less than 5 feet from the land surface decreased from about 470,000 acres in 1992 to about 320,000 acres in 1994. The decrease in area between 1992 and 1994 was caused by drought-related water supply reductions and recently implemented programs to reduce the amount of water percolating to shallow groundwater. (The monitoring program was limited to measurement of groundwater levels. There has been no region-wide monitoring for selenium levels in shallow groundwater since that done for the 1990 management plan.)

To implement recommendations of the 1990 Management Plan, four State agencies (DWR, SWRCB, DFG and Department of Food and Agriculture) and four federal agencies (USBR, USFWS, U. S. Geological Survey, and Natural Resource Conservation Service) signed a 1991 memorandum of understanding to participate in a cooperative interagency program. The program was to address the management plan's eight major recommendations: source control, drainage reuse, evaporation ponds, land retirement, groundwater management, limiting discharge to the San Joaquin River, and institutional change. (The plan's recommendations did not address disposal of drain water outside of the Central Valley.) Significant progress has been made on source control programs by individual growers and water agencies, and regulatory actions by the Regional Water Quality Control Board have reduced the number and acreage of operating evaporation ponds. Some specific examples of drainage management activities are described in Chapters 7 through 9.

Figure 4-11. Areas of Shallow Groundwater in the San Joaquin Valley



Agroforestry Research

One potential method for managing drainage impaired lands is agroforestry. Agroforestry systems integrate trees and shrubs into livestock and cropping activities to produce marketable products and/or provide resource conservation. Agroforestry principles could be applied to on-farm water management, where increasingly saline water would be applied to successively more salt-tolerant plants to reduce drainage volumes. For example, drainage water from salt-sensitive crops could be used to irrigate a salt-tolerant crop like cotton. Drainage water from the cotton would then be used to irrigate salt-tolerant trees, such as eucalyptus. Drainage water from the trees would be reused again to irrigate highly salt-tolerant plants such as saltgrass. Finally, the drainage water would be discharged into a solar evaporator where it would crystallize and be removed.

In 1985, several growers in the San Joaquin Valley, with support from the Westside Resource Conservation District, Department of Food and Agriculture, Natural Resources Conservation Service, and Westlands Water District, began using agroforestry for salinity management. Currently the Department, in cooperation with local growers, USBR, and the WRCD, is participating in two projects in the Tulare Lake region -- a 27-acre Mendota agroforestry experimental project which began in 1985, and a 622-acre Red Rock Ranch agroforestry demonstration project which began in 1993.

Results of 2020 Acreage Forecast. Table 4-13 shows the 2020 irrigated acreage forecast. The total change in irrigated crop acreage from 1995 to 2020 is forecasted to be a reduction of 325,000 acres. The reduction in crop acreage is primarily in the San Joaquin River and South Coast regions. Reductions in crop acreage are due to urban encroachment, drainage problems in the westside San Joaquin Valley, and a more competitive economic market for California agricultural products. Grain and field crops, which have lower gross earning potentials, are forecasted to be reduced by about 631,000 acres. Truck crops and permanent crops, which have higher gross earning potentials, are forecasted to increase by about 238,000 and 68,000 acres, respectively. These statewide findings are used in developing the base year and forecasted agricultural water demands.

Table 4-13. California Crop and Irrigated Acreage by Hydrologic Region, 2020 Forecast

(thousands of acres)

Irrigated Crop	*NC*	*SF*	*CC*	*SC*	*SR*	*SJ*	*TL*	*NL*	*SL*	*CR*	*TOTAL*
Grain	66	1	21	5	249	152	201	8	0	97	800
Rice	0	0	0	0	484	15	0	1	0	0	500
Cotton	0	0	0	0	15	171	888	0	0	46	1,120
Sugar beets	6	0	2	0	52	18	13	0	0	29	120
Corn	2	0	3	2	90	188	101	1	0	3	390
Other field	3	1	14	1	154	139	110	0	0	33	455
Alfalfa	62	0	20	6	147	181	238	50	24	217	945
Pasture	123	5	16	6	316	165	26	103	18	32	810
Tomatoes	0	0	8	4	141	93	130	0	0	14	390
Other truck	28	11	373	43	79	197	300	2	1	231	1,265
Almond/pistachios	0	0	0	0	127	270	198	0	0	0	595
Other Deciduous	7	6	20	3	234	153	199	0	2	1	625
Subtropical	0	0	18	117	33	10	215	0	0	32	425
Grapes	38	41	75	3	29	183	366	0	0	15	750
TOTAL Crop Area	335	65	570	190	2,150	1,935	2,985	165	45	750	9,190
Multiple Crop	0	0	150	10	70	80	100	0	0	145	555
Irrigated Land Area	335	65	420	180	2,080	1,855	2,885	165	45	605	8,635

Agricultural Water Demands

Crop water use information and irrigated acreage data are combined to generate the 2020 agricultural water demands by hydrologic region shown in Table 4-14.

Table 4-14. Agricultural Demands by Hydrologic Region (taf)

	1995		2020	
Region	**Average**	**Drought**	**Average**	**Drought**
North Coast	894	973	927	1,011
San Francisco Bay	98	108	98	108
Central Coast	1,192	1,279	1,127	1,223
South Coast	784	820	462	484
Sacramento River	8,065	9,054	7,939	8,822
San Joaquin River	7,027	7,244	6,450	6,719
Tulare Lake	10,736	10,026	10,123	9,532
North Lahontan	530	584	536	594
South Lahontan	332	332	257	257
Colorado River	4,118	4,118	3,583	3,583
Total	**33,775**	**34,538**	**31,501**	**32,333**

Environmental Water Use

The Department quantified environmental water use for the first time in Bulletin 160-93, defining it as the sum of:

- dedicated flows in state and federal wild and scenic rivers
- instream flow requirements contained in water right permits, DFG agreements, court actions, or other administrative documents
- Bay-Delta outflows required by SWRCB water rights actions
- water needs of managed freshwater wildlife areas

Unlike urban and agricultural water use, much of the environmental water use as defined above is brought about by a legislative or regulatory process. Forecasting future legislative and regulatory actions is speculative. Bulletin 160-93 used a range of 1 to 3 maf to represent future environmental demands, reflecting the uncertainty of the direction of Bay-Delta regulatory actions at the time the Bulletin was published. With the subsequent signing of the Bay-Delta Accord, Delta outflow requirements are now quantified in SWRCB's Order WR 95-6.

In the 1995 base year for Bulletin 160-98, the components of environmental water use are identical to those used in Bulletin 160-93. For the 2020 forecast, two additional sub-components have been added. The CALFED ecosystem restoration program and the CVPIA AFRP are both engaged in planning processes to identify quantities of water to be acquired throughout the Central Valley for fishery and wetland restoration and enhancement. Some of this water could be acquired through regulatory processes (e.g., the FERC relicensing process), but much of it would be acquired by water transfers. Environmental water needs identified in these planning processes have been added to the 2020 forecast. This approach does not change the Bulletin's basic definition of environmental water use, but broadens its scope by including water acquisition programs as a means of supplying environmental needs.

The following discussion provides background on and covers factors affecting the four categories of environmental water use quantified in the Bulletin. As with urban and agricultural water use, options for meeting future environmental water needs -- such as federal acquisition and transfer of water to meet CVPIA AFRP goals -- are covered in Chapter 6 and in the regional water management chapters. The environmental water use categories below are discussed in order of size -- from greatest (wild and scenic rivers) to smallest (wildlife refuges).

Flows in Wild and Scenic Rivers

Flows in wild and scenic rivers constitute the largest environmental water use in the State. Figure 4-12 is a map of California's State and federal wild and scenic rivers.

Figure 4-12. California Wild and Scenic Rivers

Note: Portions of the McCloud River, Deer Creek and Mill Creek have special state status

☞ photo: Sespe Creek, or upper Sisquoc River

The 1968 National Wild and Scenic Rivers Act, codified to preserve the free-flowing characteristics of rivers having outstanding natural resources values, prohibits federal agencies from constructing, authorizing, or funding the construction of water resources projects having a direct or adverse effect on the values for which the river was designated. (This restriction also applies to rivers designated for potential addition to the National Wild and Scenic Rivers System.) There are two methods for having a river segment added to the federal system -- congressional legislation, or a state's petition to the Secretary of Interior for federal designation of a river already protected under state statutes. No new federal designations have been made since publication of Bulletin 160-93.

However, a number of river systems within lands managed by federal agencies have been studied as candidates. For example, U.S. Forest Service draft environmental impact statements in 1994 and 1996 recommended designation of 5 streams (129 river miles) in the Tahoe National Forest and recommended designation of 160 miles in the Stanislaus National Forest. These waterways drain to the Central Valley where their flows are being used for other purposes, and wild and scenic designation would not affect the existing downstream uses.

The California Wild and Scenic Rivers Act of 1972 prohibits construction of any dam, reservoir, diversion, or other water impoundment on a designated river. As shown on Figure 4-12, some California rivers are included in both federal and state systems. No new State designations have been made since Bulletin 160-93, although the Mill and Deer Creeks Protection Act of 1995 (Section 5093.70 of the Public Resources Code) gave portions of these streams special status similar to wild and scenic designation by restricting construction of dams, reservoirs, diversions or other water impoundments on the streams.

Table 4-15 shows the wild and scenic river flows used in Bulletin 160-98 water budgets. The figures shown are based on the rivers' natural flow. (The natural flow in a river is the flow measured or calculated at some specific location that is unaffected by stream diversions, storage, imports or exports, return flows, or changes in water use created by changes in land use.) For the average year condition, the long-term average natural flow from the Department's Bulletin 1 was used. The estimated average natural flow for water years 1989-90 and 1990-91 was used for the drought condition.

As shown in the table, the North Coast wild and scenic rivers constitute the majority of the wild and scenic flows counted toward environmental water use.

Table 4-15. Wild and Scenic Flows by Hydrologic Region (taf)

	1995		*2020*	
Region	***Average***	***Drought***	***Average***	***Drought***
North Coast	17,800	7,900	17,800	7,900
San Francisco Bay	0	0	0	0
Central Coast	88	18	88	18
South Coast	0	0	0	0
Sacramento River	1,725	735	1,725	735
San Joaquin River	880	455	880	455
Tulare Lake	1,694	769	1,694	769
North Lahontan	532	239	532	239
South Lahontan	0	0	0	0
Colorado River	0	0	0	0
Total	**22,719**	**10,116**	**22,719**	**10,116**

Instream Flows

Instream flow is the water maintained in a stream or river for instream beneficial uses such as fisheries, wildlife, aesthetics, recreation, and navigation. Instream flow is one of the major factors influencing the productivity and diversity of California's rivers and streams.

☞photo: shaded riverine habitat

Instream flows may be established in a variety of ways -- by agreements executed between DFG and a water agency, by terms and conditions in a water right permit from SWRCB, by terms and conditions in a FERC hydropower license, by a court order, or by an agreement among interested parties. Required flows on most rivers vary by month and by year type, with wet year requirements generally being higher than dry year requirements.

CVPIA Anadromous Fish Restoration Program

One provision of the 1992 CVPIA directed Interior to develop by October 1995, and to implement, a program "which makes all reasonable efforts to ensure that, by the year 2002, natural production of anadromous fish in Central Valley Rivers and streams will be sustainable, on a longterm basis, at levels not less than twice the average levels attained during the period of 1967-1991". (The San Joaquin River between Friant Dam and Mendota Pool is not covered by this goal.) In response to that provision, USFWS prepared a 1995 working paper on restoration needs that was a listing of many possible restoration actions (some involving instream flows, and some not) without regard to their reasonableness. Elements of that working paper were subsequently incorporated in a December 1995 draft restoration plan, which was superseded by a revised draft prepared in May 1997. One function of the draft plans was to evaluate (at a programmatic level) the reasonableness of implementing potential restoration actions, given the authority and funding provided Interior by CVPIA. For example, a potential restoration action that would involve modifying the diversion works of a local water agency would only be reasonable if the local agency wished to participate with USBR or USFWS in the action. The revised draft plan is scheduled to be followed by an implementation plan that would review priority actions to be taken in the next three to five years.

The CVPIA tools available to USFWS and USBR to carry out the AFRP include the 800 taf of project water dedicated for environmental purposes, the authority to acquire supplemental water to achieve AFRP goals, and the many physical habitat restoration measures required in the act (e.g., restoring spawning gravel, screening diversions, improving fish passage at Red Bluff Diversion Dam). The CVP dedicated water is only available to USFWS and USBR only on CVP-controlled rivers below the major project dams. For other Central Valley waterways, the agencies are proposing to carry out a water acquisition program to buy water to meet AFRP needs. The quantity of water to be acquired is subject to available federal funding and the availability of water on the market. USBR's 1997 draft programmatic EIS for the CVPIA illustrates the costs and impacts associated with different levels of supplemental water acquisition.

Since the 1990 instream flow values used as base conditions in Bulletin 160-93, subsequent agreements or decisions have increased the instream flows used for this Bulletin's 1995 base year. The affected waterways were: the Trinity River, Mokelumne River, Stanislaus River, Tuolumne River, Owens River, Putah Creek, and Mono Lake tributaries. In addition, ten new waterways have been added to the Bulletin 160-98 instream flow water budgets -- the Mad River, Eel River, Russian River, Truckee River, East Walker River, Nacimiento River, San

Joaquin River (at Vernalis), Walker Creek, Lagunitas Creek, and Piru Creek.

Factors Affecting Future Instream Flows. As noted earlier, it is difficult to forecast future regulatory actions or agreements that could result in changes to existing instream flow requirements. Some factors likely to play a part affect decisions about future flow requirements include listings or potential listings of new fish species, habitat restoration programs, and programs to acquire water for environmental purposes.

ESA Listings of Aquatic Species. Recent decisions on federal listing of coho salmon and steelhead trout (see Chapter 2) are likely to influence water management decisions affecting these species, but the specific actions will ultimately depend on the outcome of consultations, biological assessments, biological opinions, and habitat conservation plans conducted or prepared pursuant to the ESA. In July 1997, the Governor's Executive Order W-159-97 created the Watershed Protection and Restoration Council. The Council is responsible for oversight of state activities aimed at watershed protection and enhancement, including restoration of anadromous salmonids. One of the goals of this effort is to provide sufficient protection to coho, steelhead, and other anadromous salmonids to satisfy ESA requirements. Successful implementation of this program could lessen water supply impacts of salmonid listings.

Coho salmon are found in coastal streams, and in large river systems such as the Klamath River and its tributaries. Some of the greatest potential for water supply impacts could be on the Klamath River system (including the Trinity River tributary), where USFWS is finalizing instream flow studies for several anadromous salmonids. Steelhead populations are distributed throughout coastal streams and rivers, and are also found in the Sacramento Valley. (Wild stocks of steelhead in the Sacramento River system are mostly confined to upper watershed tributaries such as Antelope, Deer, and Mill Creeks, and the Yuba River. The San Joaquin River system no longer supports a significant natural steelhead population -- most steelhead found in the system are hatchery fish.) Data from the SWP and CVP pumping plants in the southern Delta indicate that most juvenile steelhead move through the Delta during the winter and early spring, when Bay-Delta Accord restrictions to benefit other salmonids are already in place. Water supply impacts on coastal rivers and streams will have to be evaluated from a basin-specific standpoint.

The spring-run chinook salmon, a candidate species under the California ESA, traditionally spawned in the upper reaches of Central Valley rivers and their tributaries. Today, Deer, Mill, and Butte creeks are considered crucial Sacramento River tributaries for spring-run spawning. Sustaining populations of spring-run are also found in Battle Creek, and the Feather and Yuba rivers, although there are questions about the genetic integrity of these populations because of interbreeding between fall-run and spring-run salmon. As described in the previous section, portions of Deer and Mill Creeks were given special status by State legislation, to help protect the fishery. Habitat restoration actions are also being carried out at the local conservancy level for Deer and Mill creeks.

Habitat Restoration Actions. As described in Chapters 5 and 6, there are many habitat restoration programs underway, and a tremendous amount of funding is now available for restoration actions. Improving river and stream habitat through measures such as facilitating fish passage, replenishing spawning gravel, and restoring shaded riverine habitat will help in the efficient management of water dedicated or acquired for environmental purposes. Specific benefits of habitat restoration will have to be evaluated on a watershed-by-watershed basis -- at a statewide level it is not possible to quantify potential water supply implications of ongoing and future habitat restoration actions. Examples of programs or projects now underway are described in later chapters.

Water Acquisition for Instream Flows. The 1997 draft programmatic EIS for CVPIA implementation describes USBR/USFWS water acquisition alternatives for the AFRP. In developing our estimates of future environmental water needs for instream flows, we have used the amounts proposed in alternative 4 of the draft PEIS as placeholder values for this public review draft of the Bulletin. Quantification of alternative 4 flows was obtained from USBR's PROSIM operations studies. As described in the draft PEIS, these values are shown in Table 4-16.

Table 4-16. Proposed Instream Flows, CVPIA PEIS

Location	*Target Quantity(taf)*	*Long-Term Average (taf)*
Merced River	200	194
Tuolumne River	200	197
Stanislaus River	200	194
Calaveras River	30	27
Mokelumne River	70	62
Yuba River	100	87

We have used PEIS alternative 4 flows for calculation of Bulletin 160-98 future environmental water demands because the flows represent the higher end of potential federal water acquisition actions, and hence provide a conservative estimate of future demands. Under USBR's assumptions for alternative 4, the instream flows are not allowed to be exported at the Delta.

This public review draft of Bulletin 160-98 is being printed at the same time the draft CVPIA PEIS is also being reviewed by the public. USBR/USFWS have not made a final decision as to the proposed scope of CVPIA's water acquisition program. If such a decision is available before Bulletin 160 is finalized, the Bulletin's environmental water demands will be modified to reflect the decision adopted by USBR/USFWS.

CVPIA authorizes USBR/USFWS to acquire the supplemental water from willing sellers. At this time, no long-term sources (e.g., long-term contracts for water transfers) have been established -- supplemental water acquired to date has been purchased on a year-to-year basis. It is thus not possible to identify specifically how and where the supplemental water would be obtained in the future, or what other water demands might be reduced as a result of CVPIA water transfers. Chapter 6 provides more detail on how water transfers are treated in Bulletin 160 water budgets.

Instream Flow Summary. Table 4-17 summarizes instream flow quantities counted as environmental water supply. The drought year scenario shown in the table represents the minimum annual volume required. For average water years, the annual volume is computed by combining the expected number of years in each year type (wet, above normal, normal, below normal, and/or dry, as specified in the existing agreement or order) to estimate the average year requirement over a long period of time.

For the purposes of water budget computations, the Department counts instream flows as depleted if the flows go directly to a salt sink, such as the ocean. In the Central Valley where some instream flows may reach the ocean, any depletions are counted toward required Delta outflow (see following section). This approach avoids counting depletions twice -- once as instream flow and once as Delta outflow.

Table 4-17. Instream Flows by Hydrologic Region (taf)

	1995		2020	
Region	**Average**	**Drought**	**Average**	**Drought**
North Coast	1,410	1,285	1,410	1,285
San Francisco	17	9	17	9
Central Coast	20	9	20	9
South Coast	4	4	4	4
Sacramento River	3,397	2,784	3,484	2,871
San Joaquin River	1,169	712	1,843	1,386
Tulare Lake	0	0	0	0
North Lahontan	85	84	85	84
South Lahontan	107	81	107	81
Colorado River	0	0	0	0
Total	**6,208**	**4,969**	**6,969**	**5,730**

Bay-Delta Outflow

Environmental water demands for Bay-Delta outflow are computed by using operations studies to quantify SWRCB Order WR 95-6 requirements. This section briefly describes the hydrologic setting of the Delta and some of its environmental resource issues. Readers interested in detailed descriptions of Delta hydrodynamics, facilities, and environmental resources may wish to review the extensive materials prepared by the CALFED Bay-Delta program. Space constraints in this chapter do not permit us to do justice to the tremendous amount of data and information available on Delta resources. Figure 4-13 Is a location map of the Bay-Delta.

☞ aerial photo of Delta

Figure 4-13. Bay-Delta Estuary

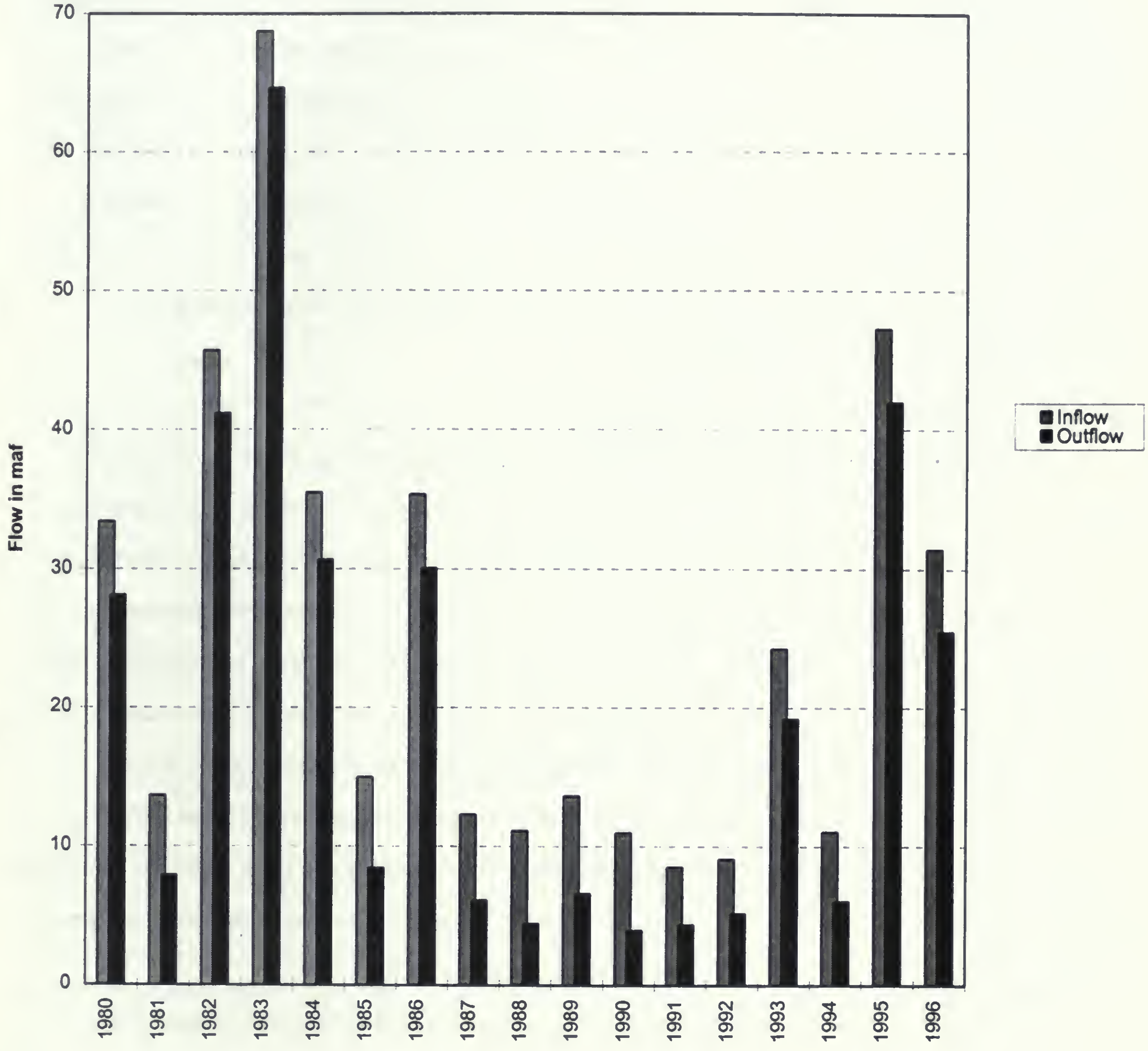
DRAFT

Hydrologic Setting. The Bay-Delta Estuary is subject to mixed semidiurnal tides--two unequal high and two unequal low tides-- every day. An enormous volume of water (an average of about one-fourth of the Estuary's total volume), moves in and out of the Estuary with each tidal cycle. Tidal action and Delta outflow are two important physical processes which establish salinity gradients and carry sediments through the system. Tidal action and Delta outflow cause seaward-flowing fresh water from the rivers to mix with denser landward-flowing salt water from the ocean.

There are three major components to Delta water inflow: precipitation, inflow from the Sacramento and San Joaquin rivers, and inflow from the east side streams (including the Calaveras, Mokelumne and Cosumnes rivers). Figure 4-14 shows annual inflow and outflow values for 1980-1996. For this period, the annual inflow to the Delta was 25.7 maf, more than 75 percent of which was contributed by the Sacramento and San Joaquin rivers.

Delta outflow is the calculated amount of water flowing past Chipps Island, at the western edge of the Delta, into Suisun Bay. Delta outflow is small compared to the average tidal flow at the Golden Gate or Chipps Island. The magnitude of Delta outflow controls salt water intrusion from the ocean into the estuary. The magnitude of Delta outflow also influences the distribution of many estuarine fishes and invertebrates. Generally, the greater the outflow, the farther downstream estuarine fish and invertebrates occur. The relationship between Delta outflow and abundance of fish and invertebrates is much less clear. However, species such as longfin smelt and juvenile splittail show strong correlations between abundance and Delta outflow. The effects of outflow on species can vary depending on the time of year and type of water year.

Figure 4-14. Historic Delta Inflow and Outflow 1980-96



☞photo: Suisun Marsh

Suisun Bay, the first embayment below the Delta, receives a high freshwater inflow that contributes much of the dissolved nutrients needed to support estuarine food chains. The Bay's extensive areas of shallow water habitat are an important ecological feature of the Estuary. Adjacent to Suisun Bay is Suisun Marsh which includes about 58,600 acres of diked managed wetlands, tidal marsh, and adjacent grasslands; 29,500 acres of bays and waterways, and a buffer zone of 27,900 acres of varying land use. The Suisun Marsh is one of the largest contiguous brackish water marshes in the United States. Today, nearly half of the waterfowl and shorebirds migrating on the Pacific Flyway pass through the Estuary each year, using the marsh and wetlands as feeding and resting stations.

☞photo: Delta smelt

Delta Fish Species of Special Concern -- Anadromous and Resident Delta Species. About two-thirds of California's salmon migrate through the Delta. These salmonids include those having commercial importance (fall-run chinook salmon), as well as listed or candidate species (winter-run chinook, spring-run chinook, and steelhead trout). Resident fish species of special concern include Delta smelt (listed as threatened under both the state and federal ESAs) and splittail (proposed for federal ESA listing). Habitat needs of anadromous and resident Delta species of special concern were reflected in actions taken in the Bay-Delta Accord and in SWRCB's Order WR 95-6. The Accord's provisions for coordination of CVP and SWP operations in the Delta with the presence of fish species of concern have been reflected in actions by the CALFED Operations Group to reduce Delta exports at times when monitoring indicated that significant numbers of fish were present in the southern Delta.

Managing CVP and SWP Delta operations under near real-time conditions requires extensive data collection and monitoring support. The Interagency Ecological Program, a cooperative effort of nine state and federal agencies (DWR, DFG, SWRCB, USBR, USFWS, USEPA, NMFS, USACE, and USGS), acquires and disseminates near real-time fish distribution and abundance data used by the CALFED Operations Group. (The IEP also performs baseline monitoring of benthic, phytoplankton, zooplankton, and fish populations, and conducts studies on fish species of concern.)

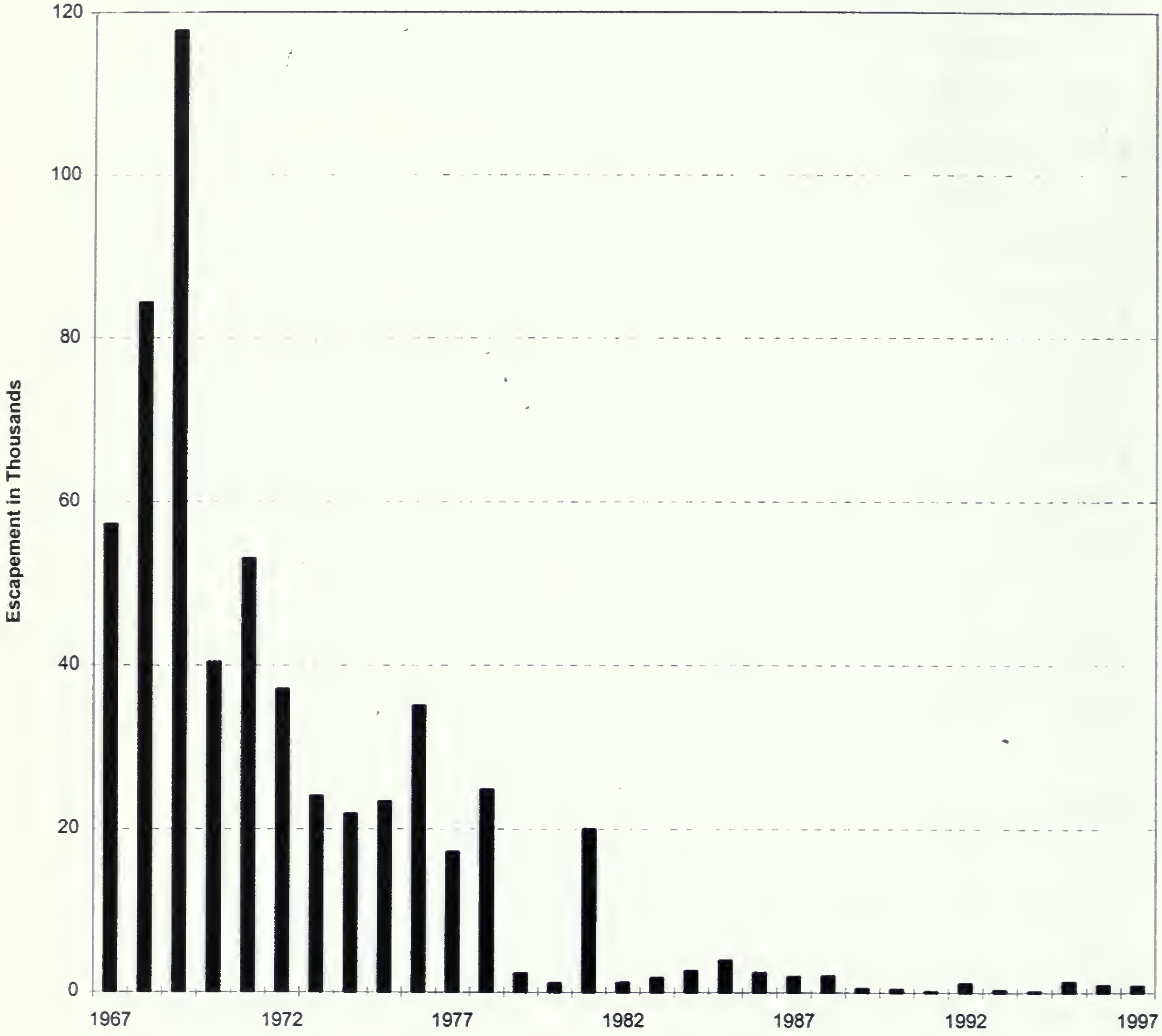
Recovery Efforts for Winter-run Chinook Salmon

As indicated by the plot of winter-run salmon escapement shown in Figure 4-15, there has been a long-term decline in the species' population. The ultimate goal for recovery of winter-run salmon would be restoration of a self-sustaining, naturally spawning population. Two efforts are being conducted to help achieve this goal -- a captive broodstock program and an artificial propagation program. The purpose of the broodstock program is to maintain the genetic composition of the existing population, and that of the artificial propagation program is to stabilize and increase the naturally spawning population.

Discussions among State and federal agencies and stakeholder groups in 1991 and 1992 led to the creation of a program to evaluate the feasibility of rearing Sacramento River winter-run fry in captivity, so that a broodstock would be available if wild winter-run fish were to disappear. (The population's small size makes it vulnerable to catastrophic loss of a year class, such as a loss that could be caused by a chemical spill in the vicinity of winter-run spawning areas. The captive broodstock would provide an alternate source of genetic material as insurance against such a loss.) Agencies participating in funding the program include USBR, USFWS, NOAA, DWR, and DFG. Rearing facilities were established at the University of California's Bodega Marine Laboratory and the California Academy of Sciences' Steinhart Aquarium. Juvenile fish from the 1991 year class were delivered to these facilities in 1992. The parent broodstock were wild winter-run captured in the Sacramento River. Presently, fish from four year classes are being held at the facility.

The artificial propagation program entails trapping known wild adult winter-run fish, spawning them in a controlled environment, and rearing the offspring for release back to the river system. As adults, the artificially propagated fish would return to winter-run spawning areas and commingle with wild winter-run. Artificial propagation activities were originally begun at USFWS's Coleman National Fish Hatchery on Battle Creek, but fish reared at Coleman imprinted on Battle Creek water and returned there to spawn, rather than going to the upper Sacramento River as desired. (There were also difficulties associated with distinguishing between winter-run and spring-run chinook, in selecting the fish to be propagated. Better genetic identification techniques have been developed to address this problem.) Construction of a temporary rearing facility on the Sacramento River mainstem has been proposed as a means to avoid the straying of returning adults. The rearing facility and the broodstock program would both be temporary actions to sustain the winter-run until natural spawning would be sufficient to allow the species to recover.

Figure 4-15. Winter-run Salmon Escapement



☞photo: Coleman National Fish Hatchery

Introduced Species in the Bay-Delta. Populations of native species of special concern are affected by a variety of factors, many of which are not related to Delta outflow. One nonflow factor now receiving more attention is competition from introduced aquatic species (see Chapter 2 for a description of the National Invasive Species Act of 1996). Introduction of non-native species into an ecosystem can alter the pre-existing balance achieved among the native species. Native species' populations can be reduced, for example, when introduced species out-compete the native species for food or otherwise alter the food chain, or when introduced species prey upon native species.

In the Bay-Delta, new introductions are occurring in a system that already has numerous introduced species. Researchers estimate that the Bay-Delta is now home to at least 150 introduced plant and animal species, some of which were introduced deliberately (planting of game fish species such as striped bass) and others whose arrival was accidental (discharge of invertebrates in ship ballast water). The Asian clam, for example, was first detected in the Bay in 1986, and has now become the most abundant mollusk in the northern part of the Bay. This clam is a voracious feeder on the phytoplankton upon which other aquatic species depend. The zebra mussel (see photo) -- which has caused millions of dollars of damages in the Great Lakes states -- has not yet been detected in the Delta, but experts believe that it may be only a matter of time before the mussel arrives.

☞photo: zebra mussel

Quantifying Delta Outflow Requirements. SWRCB Order WR 95-6 established numerical objectives for salinity, river flows, export limits, and Delta outflow. DWRSIM operations studies were used to translate these numerical objectives into Delta outflow requirements for average and drought year scenarios. The studies computed outflow requirements of approximately 5.6 maf in average years and 4.0 maf in critically dry years.

Wetlands

The wetlands component of environmental water use is based on water use at freshwater managed wetlands, such as federal national wildlife refuges and state wildlife management areas. The following text reviews the status of wetland acreage in California and existing wetland management programs, then discusses quantification of water demands and supplies for wetlands.

In general, wetlands can be divided into saltwater and brackish water marshes (usually located in coastal areas) and freshwater wetlands (generally located in inland areas). Five areas of California contain the largest remaining wetlands acreage in the State. These areas are the Central Valley, Humboldt Bay, San Francisco Bay, Suisun Marsh, and Klamath Basin. The majority of the State's wetland protection and restoration efforts are occurring in these areas. In California today, nontidal wetlands usually depend on a supplemental water supply. Thus, protecting and restoring nontidal wetlands may cause additional demands on freshwater supplies.

☞ photo: managed wildlife refuge

Wetlands Policies and Programs. Many programs and policies have been adopted by federal, State and regional agencies and private entities to protect and restore wetlands in California. These regulations and policies are intended to protect existing wetlands, improve wetland management practices and increase wetland habitats. Several of the more recent wetland programs and policies are discussed below.

CALFED Bay-Delta Program. Ecosystem restoration is a large part of the CALFED program. CALFED's draft Ecosystem Restoration Program Plan proposes habitat restoration goals that include restoring 64,000 acres of seasonal and perennial wetlands and 2,000 acres of riparian habitat, returning 37,000 to 57,000 acres to tidal action and enhancing 8,000 acres of existing seasonal wetlands. About 1,700 acres of wetland restoration projects were funded under the Accord's Category III program in 1995 and 1996.

Central Valley Project Improvement Act. Water is to be provided to 15 existing wildlife refuges identified in USBR's Refuge Water Supply Report and to the five habitat areas identified in the USBR/DFG San Joaquin Basin Action Plan/Kesterson Mitigation Plan. The Act directed the Secretary to provide firm water supplies for the 15 Central Valley refuges, and to provide two-thirds of the water supply needed for full habitat to the SJBAP refuges. By 2002, the Secretary is to provide, by purchases from willing sellers, the northern and southern wetlands areas with water supplies needed for optimal habitat development.

USBR/USFWS were also required to prepare a report by September 1997 which investigates the method of improving water supplies in the Central Valley for existing private wetlands and for 120,000 acres of new wetlands. The 120,000 acres is based on the wetland restoration objective of the Central Valley Habitat Joint Venture Report. USFWS's report is currently in preparation.

Additionally, the act required that financial incentives be made available to farmers within the CVP service area for flooding agricultural lands to provide waterfowl habitat. The incentives represent cost-sharing for water purchases, pumping costs, facilities construction (water control structures, ditches, etc.) and upgrades or maintenance of existing facilities. CVPIA caps the funding for this program at $2 million per year, and the program terminates in 2002.

California Wetlands Conservation Policy

In August 1993, the Governor announced the "California Wetlands Conservation Policy." The goals of the policy are to establish a framework and strategy that will:

- Ensure no overall net loss and achieve a long-term net gain in the quantity, quality, and permanence of wetlands acreage and values in California in a manner that fosters creativity, stewardship, and respect for private property
- Reduce procedural complexity in the administration of State and federal wetlands conservation programs.
- Encourage partnerships to make landowner incentive programs and cooperative planning efforts the primary focus of wetlands conservation and restoration.

The policy recommends the completion of a statewide inventory of existing wetlands which will then lead to the establishment of a formal wetland acreage goal. This inventory is in progress and to date about one-half of the State has been inventoried. The Resources Agency expects these policies to result in improved status for 30 to 50 percent of the State's wetlands by the year 2010. Based on the estimate of 450,000 acres of existing wetland in the State, as much as 225,000 acres of wetland would be improved, restored or protected.

☞photo: waterfowl at wetlands

North American Waterfowl Management Plan--Joint Ventures. In 1986, the North American Waterfowl Management Plan was signed by the United States and Canada. In 1996 the Plan was updated, and Mexico became a signatory. The NAWMP provides a broad framework for waterfowl management in North America through the year 2010; it also includes numerical goals for waterfowl populations and for wetland and upland habitat protection restoration, and enhancement. Implementing the NAWMP is the responsibility of designated joint ventures, in which governmental agencies and private organizations pool their resources to solve waterfowl habitat problems and to address habitat needs for other species that benefit from wetlands. There are now four NAWMP joint ventures whose geographic boundaries include part of California. A fifth joint venture is being discussed for Southern California. The four existing joint ventures in California are described below.

The Central Valley Habitat Joint Venture. The CVHJV, established in 1988, was the first joint venture formed in California. The CVHJV adopted six goals for the Central Valley:

- Protect 80,000 acres of existing wetlands through fee acquisition or conservation easement
- Restore (and protect) 120,000 acres of former wetlands
- Enhance 291,555 acres of existing wetlands
- Enhance water-based habitat on 443,000 acres of private agricultural land
- Secure 402,450 af of water for 15 existing refuges in the Central Valley
- Secure CVP preference power for public and private lands dedicated to wetland management (i.e., provide access to low-cost power generated at CVP facilities)

In 1990, the Legislature authorized the Inland Wetlands Conservation Program within the Wildlife Conservation Board. This program carries out some of the objectives of CVHJV by administering a $2 million per year program to acquire, improve, buy, sell, or lease a wetland habitat. As of January 1996, $13.6 million has been authorized for the acquisition of 867 acres of existing wetlands, for acquisition and enhancement of 5,004 acres of degraded wetlands, and for enhancement of 46,622 acres of existing wetland and associated upland nesting habitat. Through 1996, the CVHJV has made the following progress toward its goals:

- 67,000 existing wetland acres were protected through acquisition or easements
- 42,000 acres were restored and protected, and 6,000 acres acquired for restoration
- 45,000 acres of wetland per year have been enhanced. (In many cases, wetlands have received multiple, sometimes annual, enhancements because of their location or participation in various CVHJV programs.)
- 152,000 acres of agricultural land were enhanced for wildlife in 1995-1996
- 399,000 acre feet of CVP water were delivered in the 1995-1996 irrigation season.

The CVHJV projects that in the next ten years, 5,000-6,000 acres of wetlands per year will be restored, and approximately 50,000 acres per year will be affected by enhancement projects. In addition, the CVHJV anticipates that the objective to protect 80,000 acres of existing wetlands will be accomplished with fee or easement acquisition of an additional 12,200 acres.

The Pacific Coast Joint Venture. This joint venture encompasses coastal wetlands, major rivers and adjacent uplands from northern British Columbia to the northern edge of San Francisco Bay. In California, there are two focus areas with strategic plans outlining specific target areas and acreage objectives. The objectives for the northern focus area (Del Norte and Humboldt counties) are shown below. Almost all the wetlands are coastal projects with little or no freshwater requirements.

- Maintain 22,000 acres of seasonal wet pasture land in agricultural usage compatible with water-associated wildlife
- Permanently protect an additional 10,500 acres of key wetlands through easements or fee acquisitions
- Protect, restore and enhance 10,100 acres of wetlands on existing public lands
- Assist landowners to protect, enhance and restore 5,000 acres through various cooperative projects

Objectives of the southern focus area (Mendocino, Sonoma and Marin counties excepting watersheds draining to San Francisco Bay) are shown below. Approximately half of the acreages are inland (nontidal) habitats requiring fresh water.

- Permanently secure through fee acquisition or easements an additional 20,000 acres of coastal and interior wetlands, riparian habitats and associated uplands.
- Restore 3,500 acres of reclaimed coastal and interior wetlands on both private and public lands.
- Enhance 5,500 acres of coastal and interior wetlands and riparian habitats on public and private lands.

The Intermountain West Joint Venture. This Joint Venture encompasses parts of Canada and Mexico and all or part of eleven western states, including eastern California. The California action group has completed a working agreement and drafted plans for six focus areas. Acreage goals for acquisition, restoration and enhancement have not yet been determined.

The San Francisco Bay Joint Venture. This joint venture was established in 1995 with the goal to protect, restore, increase and enhance wetlands, riparian habitat and associated uplands throughout the San Francisco Bay region to benefit waterfowl, other wildlife, and fish. The management board is working out a memorandum of understanding and drafting an implementation strategy. Formal acreage goals and time lines for acquisition and restoration projects will then be established. It is expected that many of the areas protected or restored by the SFBJV will be tidal areas with little or no fresh water requirement.

Refuge Water Conservation Programs. In the spring of 1997, the Refuge Water Supply Interagency Coordinated Program Task Force was formed as an outgrowth of discussions in CALFED and CVPIA programs regarding the need to have best management practices for water conservation on wildlife refuges. The goal of the task force is to develop a common methodology for water management planning, including water conservation actions, for the federal, State, and private refuges covered in CVPIA's refuge water supply provisions. A draft document containing BMPs or efficient water use guidelines for the refuges is scheduled to be released for public review in 1998.

Wetlands Water Demands. The Bulletin quantifies applied water needs only for managed wetlands because other wetlands types such as vernal pool or coastal wetland habitats use naturally-occurring water supply such as precipitation or tidal action. Managed wetlands are defined for this purpose as impounded freshwater and nontidal brackish water wetlands or agricultural lands flooded to create wildlife habitat. Of the estimated 450,000 acres of wetlands in the State, approximately 75 percent (335,000 acres) are managed. (Although agricultural lands flooded for wildlife habitat are not usually considered wetlands, they provide important winter feeding habitat for migratory waterfowl.) Figure 4-16 shows California's publicly managed wetlands.

Managed wetlands are owned and operated as State and federal wildlife areas, private wetland preserves owned by nonprofit organizations, or private duck clubs. Agricultural lands flooded to create waterfowl habitat are primarily rice fields in the Sacramento Valley and corn or other small grain crops in the Delta. Managed wetlands receive water from several sources including groundwater, local surface water, imported surface water from the CVP, the SWP, and local projects, as well as agricultural return flows. Table 4-18 shows wetlands water demands by region.

Figure 4-16. Publicly Managed Fresh Water Wetlands

1. Shasta Valley W.A.
2. Butte Valley W.A.
3. Lower Klamath N.W.R.
4. Tule Lake N.W.R.
5. Clear Lake N.W.R.
6. Modoc N.W.R.
7. Ash Creek W.A.
8. Willow Creek W.A.
9. Honey Lake W.A.
10. Upper Butte Basin W.A.
11. Sacramento River N.W.R.
12. Sacramento N.W.R.
13. Delevan N.W.R.
14. Gray Lodge W.A.
15. Butte Sink N.W.R.
16. Colusa N.W.R.
17. Sutter N.W.R.
18. Yolo Bypass W.A.
19. Stone Lakes N.W.R.
20. Suisun Marsh W.A.
21. North Grassland W.A.
22. Kesterson N.W.R.
23. San Luis N.W.R.
24. Merced N.W.R.
25. Volta W.A.
26. Los Banos W.A.
27. Mendota W.A.
28. Pixley N.W.R.
29. Kern N.W.R.
30. San Jacinto W.A.
31. Imperial W.A.
32. Salton Sea N.W.R.

N.W.R = National Wildlife Refuge
W.A. = State Wildlife & Ecological Reserve

Table 4-18. Wetlands Water Demands by Region (taf)

	1990		1995	
Region	**Average**	**Drought**	**Average**	**Drought**
North Coast	325	325	325	325
San Francisco	160	160	160	160
Central Coast	0	0	0	0
South Coast	27	27	31	31
Sacramento River	632	632	665	665
San Joaquin River	230	230	336	336
Tulare Lake	50	50	68	68
North Lahontan	18	18	18	18
South Lahontan	0	0	0	0
Colorado River	39	38	44	43
Total	**1,481**	**1,480**	**1,647**	**1,646**

Summary of Environmental Water Demands

Table 4-19 shows base 1995 and forecasted 2020 environmental water demands by hydrologic region. The large values in the North Coast region illustrate the magnitude of demands for wild and scenic rivers in comparison to other environmental water demands.

Table 4-19. Summary of Environmental Water Demands by Hydrologic Region (taf)

	1995		2020	
Region	**Average**	**Drought**	**Average**	**Drought**
North Coast	19,544	9,518	19,545	9,518
San Francisco	5,762	4,294	5,762	4,294
Central Coast	108	27	108	27
South Coast	31	31	35	35
Sacramento River	5,825	4,222	5,951	4,344
San Joaquin	2,302	1,420	3,087	2,205
Tulare Lake	1,752	827	1,771	846
North Lahontan	635	341	635	341
South Lahontan	107	81	107	81
Colorado River	39	38	44	43
Total	**36,104**	**20,799**	**37,043**	**21,734**

Chapter 5. Technology in Water Management

This chapter highlights the present status and anticipated development of water management technologies, in counterpart to Chapter 2, which focuses on the status of institutional and programmatic water management actions. Review of water management technologies provides an important foundation for the evaluation of water management options described in later chapters of the Bulletin. For example, it is a common public perception that desalting will solve most of California's future water problems. However, the current and reasonably foreseen state of the technology suggests that it will be used to meet relatively small, specialized needs. This chapter provides some case histories of application of selected technologies, and illustrates a few innovative examples.

Demand Management Technologies

Urban Residential Technology

Technology will further improve residential water use efficiency. As discussed in Chapter 4, advances over the past twenty years have come primarily from redesign of plumbing fixtures to meet new State and federal standards. In the future, there will be further improvement to fixtures, along with water-efficient home appliances such as clothes washers and water heating systems. In addition, technology is emerging to better quantify the end uses of water in the residential sector, yielding data to more accurately forecast urban water demand and optimize the allocation of demand management program resources.

Plumbing Fixtures. State law requires all toilets sold or installed in California to use no more than 1.6 gallons per flush. However, these standards have pushed traditional gravity operated toilets to the limit of acceptable operation. Significant additional savings could come from the use of pressure-assisted toilet design in the residential sector.

Gravity toilets rely on the force of gravity to flush waste from the toilet bowl. When the flush mechanism is activated, water held in storage above the bowl flows through the rim holes and center jet. The water level in the bowl and trap way rises to flow over the crest of the trap way, creating a siphon action which empties the bowl. As the water level in the bowl drops, air enters the trap way and the siphon is broken. Performance of the gravity flow design is limited by the flow rate achieved through the bowl under the force of gravity, placing a limit on the potential for reducing the amount of water used in each flush.

Pressure-assisted toilets employ pressurized flow into the bowl in conjunction with siphon action to give acceptable operation with less flushing water. The increased flow rate (more than 70 gallons per minute compared to about 25 GPM for gravity designs) provides greater force to remove solids from the bowl and hastens the start of the siphon action. In addition, the surge of water from a pressure-assisted toilet is more effective at pushing waste through the drain line.

In the past, use of pressure-assisted technology was limited to the commercial sector due to cost and increased noise associated with the design. However, current residential designs using 1.6 gallons or less per flush are less expensive than previous models and only slightly noisier than gravity toilets. Future residential designs are expected to require 0.5 gallons or less per flush, saving more than one gallon per flush compared to current 1.6 GPF models.

Clothes Washers. Horizontal-axis clothes washers, also referred to as tumble washers, use significantly less water than the traditional vertical-axis, central agitator machines. Rather than fully immersing the clothes to wash them, the tub of the tumble washer rotates through a horizontal axis in alternating directions to lift and tumble the clothes through a pool of water. Recent studies show that tumble washers use about 25 to30 percent less water than central agitator models. The horizontal orientation of the wash tub allows for faster spin cycles, resulting in 30 percent better moisture removal over conventional models.

As of 1997, five American manufacturers, and three overseas manufacturers produce horizontal-axis tumble washers that meet Consortium for Energy Efficiency specifications. The criteria include an energy factor, water factor, and estimated remaining moisture content. Table 5-1 summarizes the results of a recent study comparing the water and energy use of tumble washers to traditional central agitator machines.

Table 5-1. Potential Estimated Annual Water & Energy Use and Potential Savings for Horizontal Axis Washers[1]

	Use (Standard Washers)	*Use (Horizontal Axis Washers)*	*Potential Savings*
Electricity	1,200 kWh	600-900 kWh	300-600 kWh
Natural Gas	43 therms	20-30 therms	13-23 therms
Water	15,300 gal	9,800-12,000 gal	3,300-5,500 gal[2]

1. Includes estimated savings for annual clothes dryer use. "Electricity" assumes electric water heating and electric drying. "Natural Gas" assumes gas water heating and gas drying. These energy saving estimates do not apply to machines using cold water cycles.

2. The high end of estimated annual savings per household is based on DOE standards and a 1994 Proctor & Gamble survey with an average cumulative total of seven to eight wash loads weekly.

Currently tumble washers in the United States range in price from about \$900 to \$1,200, about 2 to 3 times that of central agitator machines. However, as the market grows, prices are expected to decrease to within about \$200 dollars of central agitator models. A recent survey of appliance retailers showed the residential market for tumble washers could increase from about 2 percent at present to between 5 and 20 percent over the next five years.

Water Heating. Hot water demand systems save water by eliminating the need to drain cold water sitting in the pipe between the water heater and the plumbing fixture, or by reducing the distance between the heater and fixture. Demand systems come in two basic configurations: central storage tank and tankless systems. Central storage tank systems are based on traditional water heater and plumbing systems, modified with the addition of a valve to open a loop back to the hot water tank, and a pump to push the cold water back to the water heater while drawing hot water into the pipe. When hot water reaches the fixture, the loop closes and hot water exits the fixture. Tankless systems, also known as instantaneous or on-demand water heaters, heat water only when needed. They can be located near the plumbing fixture to reduce the amount of cold water that must be displaced for hot water to reach the fixture. Because they do not store hot water, tankless systems can save energy by eliminating standby losses.

Water savings depend on the amount of water to be displaced before hot water reaches the fixture (or the amount of water that would have been displaced, in the case of tankless systems). Measurements by the California Energy Commission show that about 2 times the pipe volume between the water heater and the fixture must be replaced before hot water reaches the fixture, due to heat lost to the pipe. A study of potential water savings in southern California showed that hot water demand systems could save approximately 30 gallons per day per unit, or about 10,000 gallons per year.

Flow Trace Analysis. Water resource planners use information on the breakdown of water use within the residential sector to forecast future demand and to allocate demand management program resources. In the past, the breakdown was estimated from aggregate data obtained from water meters and assumptions about the water use of various fixtures and appliances. However, a 1995 study in Boulder, Colorado showed that detailed information on water use patterns could be gathered through analysis of data obtained from data loggers attached to residential water meters. The traces have sufficient detail to recognize flow signatures of individual fixtures and appliances. The technique also provides information on the breakdown between indoor and outdoor water use. Based on the success of the Boulder study, a larger study was organized. The goal of the North American Residential End Use Study is to collect a two-week data sample from 1,200 homes in 12 cities. The flow trace data will be disaggregated into the major end use components of residential use: toilets, showers, baths, faucets, dishwashers, clothes washers, and leaks. This data will be combined with information from a survey of study participants to construct a residential water model. The data collection phase of the study is scheduled to conclude in March 1998.

Commercial, Institutional, and Industrial Technology

Plumbing Fixtures. The water savings potential of 0.5 gallon per flush toilets also applies to the commercial sector. In addition, while State law requires that urinals use no more than an average of 1.0 gallon per flush, this water requirement could be further reduced or eliminated through the use of waterless urinals. Waterless urinals attach to standard plumbing stubs, but require no flushing water to operate. Urine drains by gravity from the bowl through a liquid seal that provides a barrier to bacteria and odor. The specific gravity of the liquid seal is lower than that of the urine, which flows through the seal and into the sewer pipe. Also, there is no need for a water supply line or flush valve.

Water savings from waterless urinals depends on the frequency of use and the flushing water requirement of the fixture that is replaced. A study in southern California showed potential savings ranging from about 4,000 gallons per fixture per year in office buildings, to about 20,000 in airports and movie theaters. Savings could be greater in more frequently- used facilities. In

1995, the U.S. Navy equipped sample bathroom facilities at the Naval Air Station North Island in San Diego with waterless urinals. The study found that replacement saved about 45,000 gallons of water per year, with a pay-back period of about 3 years. Based on the success of the trial, more than 200 waterless urinals were later installed at the station.

☞Photo: Cooling Tower

Cooling Towers. The largest use of water in the industrial sector is for cooling. Water is used to cool heat-generating equipment in locations such as power plants, products such as injected plastics and forged metals, and food products and containers in canneries. The most water-intensive cooling method is once-through cooling, where water contacts and lowers the temperature of a heat source, then is discharged to waste. Recirculating cooling tower systems reduce water use by using the same water for several cycles.

The majority of cooling towers in California are recirculating evaporative systems, where the temperature of the cooling water is reduced through evaporation. As cooling water is recycled through the tower, the concentration of salts in the water increases. Salt build up must be managed to avoid scaling on condenser tubes, which results in reduced heat transfer efficiency. "Blowdown" is the release of some of the circulating water to remove the suspended and dissolved solids left behind due to evaporation. Make-up water is added in place of the blowdown to reduce the total dissolved solids. Water savings can accrue by minimizing blowdown or by converting to a dry cooling process based on air heat exchangers.

Blowdown can by minimized by treating the recirculating water with sulfuric acid or ozone to control scaling and biological fouling, mechanical filtration of solids, and the use of conductivity sensors and automatic valves to precisely control the blowdown/makeup process. Savings can be maintained through regular calibration of the conductivity sensors. A 1996 study conducted for the Metropolitan Water District of Southern California suggested that the majority of cooling tower water savings in southern California could be realized through the addition and/or calibration of conductivity controllers. Water savings estimates ranged from about 400 to more than 900 gallons per day, per site.

Air heat exchangers use fans to blow air past finned tubes carrying the recirculating cooling water. The Pacific Power and Light Company's Wyodak Generating Station in Wyoming uses dry cooling to eliminate water losses from cooling-water blowdown and evaporation. The processed steam is condensed by routing it through finned carbon steel tubes as fans force air, at a rate of 45 million cubic feet per minute, through an 8 million square foot finned-tube surface. This technique results in a water requirement of 300 gallons per minute, compared to about 4,000 GPM of make-up water for equivalent evaporative cooling.

Agricultural Technology

Irrigation Systems. Many terms are used in describing the performance of irrigation systems, but the two most important are Distribution Uniformity and Seasonal Application Efficiency, as defined in Chapter 4. Irrigation experts generally agree that an 80 percent DU is achievable by all irrigation systems and is an upper limit for existing systems. With a maximum DU of 80 percent, an SAE of between 73 to 80 percent is possible. With today's systems, SAEs of more than 80 percent indicate under-irrigation, potentially resulting in a reduction of crop production and an increase in soil salinization. Whether a gravity or pressurized system, a well-designed and well-managed irrigation system appropriate to the field's terrain, soil, crop, and flow constraints can achieve the maximum DU and result high SAE, provided the irrigation water supply is of adequate quality and is available when needed at the proper rate of delivery.

Adoption of new irrigation technology to reduce applied water must result in a reduction in at least one of the following: deep percolation, tailwater runoff, evapotranspiration, or leaching requirement. Reduced deep percolation and tailwater runoff could be achieved through improvement in DUs and irrigation management. Evapotranspiration could be reduced by either minimizing losses from surface evaporation, or intentional underirrigation with no loss in production or quality. Reducing the leaching requirement (the amount of water used to leach salts from the soil) is not a goal because insufficient leaching results in salinization of the soil, rendering it less productive.

Gravity (Surface) Irrigation Systems. These systems use the soil surface to spread and move water on and over a field. The field is optimally rectangular in shape, with the water entering the field from the highest corner. The water moves over the surface of the soil, eventually covering the whole soil area that is intended to be irrigated. While the water is in contact with the soil, it infiltrates the soil to replenish soil moisture. The rate of infiltration varies by soil type and time (a sandy soil has a much higher infiltration rate than a clay soil). All soils have a maximum infiltration rate at the beginning of irrigation. The longer the water is in contact with the soil, the more the infiltration rate decreases, and in some soils it decreases to where almost no water infiltrates.

The most important factors for achieving high DUs are intake opportunity time and the variability of soil infiltration rate. The IOT is the amount of time that the applied irrigation water is in contact with the soil. The IOT varies within an irrigated field. On some furrow systems, usually the part of the field closest to the source of water would have the highest IOT, and the lower half of the field the lowest. For high DUs, the IOT within a field must have a high uniformity. In addition, the homogeneity of the soil within a field will affect the DU. All fields have some variability in soils, which means the infiltration rate will vary. Different soils with the same IOT will have a different amount of water that infiltrates the soil. The greater the soil variability, the more soils infiltration rates will vary, resulting in a lower DU.

The most important considerations for achieving high SAE are the timing of irrigation and applying the correct amount of water (and having a high DU). With most surface systems, the grower must make a decision as to how dry the soil can become before an irrigation is applied. This is called the allowable depletion. It is a decision by the grower based on the field, the irrigation system design, the crop, the soil depth, and other factors. If a grower has an AD of 3 inches (i.e., the soil must be infiltrated to a depth of 3 inches to bring the soil moisture back up to field capacity), then the irrigation should occur when the soil in the field has dried to that level. The amount of water to be applied over the field should be more than 3 inches (due to the fact that water cannot be applied with a DU of 100 percent). Irrigating before reaching the AD could result in an over-application of water, and a lower SAE. Irrigating after reaching the AD might result in an under application, and an overly high SAE, which is not desirable, because plant stress due to underirrigation may occur, with potential loss in production and/or quality.

The major types of gravity surface systems used in California -- furrow, border strip, and level basin -- are discussed in the following paragraphs.

Furrow is the most common type of gravity system, and is generally used for trees, vines, truck crops, and some field crops. Channels or corrugations are cut or pressed into the soil of a field, usually one furrow between planted rows of crops. Furrow shapes and depths vary, depending on the crop and field. Furrow lengths vary, depending on soil infiltration rates and slopes (among other factors). Efficient furrow systems have a slight grade, sloping down from the head of the field (where water enters the furrows), to the bottom of the field. Water is delivered to the furrows either using an earthen ditch and siphon tubes, gated pipe, or underground piping and above ground valves. In furrow systems the only portion of the soil surface in the field in contact with irrigation water is soil in the channel itself. Usually, between 20 to 50 percent of the soil surface in a furrow irrigated field comes in contact with the irrigation water.

When irrigating sloping furrow systems, tailwater runs off the end of the furrows. A tailwater recovery system is needed to reuse this tailwater, either on the same field, or on another field. Efficient furrow management requires a relatively high flow at the beginning of the irrigation, to get the water down the furrow quickly, then the flow is cutback to reduce tailwater losses.

Furrow systems can be designed and operated to achieve good SAE for a range of ADs, except for very small ADs. For instance, a furrow system used to irrigate at an AD of 4 inches could result in a DU of 80 percent. If irrigations were scheduled correctly, a high SAE would result (up to 80 percent). If this same system were used to irrigate at an AD of 6 inches, the DU would probably be about the same, as would the SAE (if the irrigations were scheduled correctly). The AD changes as the root zone changes. Therefore, the early season irrigation of annual crops will not be as efficient as later season irrigations, because the early season AD would be small (shallow root depths), while the later season AD would be large (deep roots). Technologies and actions to optimize DUs and increase SAEs for furrow systems are outlined below:

(1) Increasing the advance rate by dragging torpedoes (heavy metal cylindrical devices) within a furrow smooths and compacts the soil surface. This is most effective for early season irrigations, where the soil surface is rough due to tillage, and the soil intake rate is high.

(2) Shortening the length of the furrow will result in an improved advance ratio. (Shortening furrows results in an increase in the number of furrows, which can also increase the cost (labor, hardware, preparation) of irrigation.)

(3) Laser leveling of fields to achieve a uniform slope, and a steeper slope (if possible), will increase the advance rate.

(4) Increasing the initial flow into each furrow can improve the advance ratio. The flow rate must not be high enough to cause furrow erosion.

(5) Using surge irrigation, a technique where short term opening and closing of valves provides water to the furrows, resulting in the water "surging" down the furrow. (This technique is better suited to some soil types than others.) This technique will improve the uniformity of IOT in a furrow. It requires a surge valve designed for this application, and can easily be automated.

(6) Reducing the flow rates in each furrow after the water has reached the end of the furrow is essential to reducing the amount of tailwater produced.

(7) Using a properly planned and designed tailwater recovery system, along with using the captured tailwater efficiently on the same field or other irrigated fields, is essential to optimizing SAE.

Border-Strip systems are generally used for alfalfa and pasture, but can be used on various field crops and trees and vines. A field is divided into a number of strips, usually between 20 to 100 feet wide. Low levees, or borders, divide each strip. Each strip has a slight slope from the head of the strip to the bottom, and ideally little or no slope between the sides. Water is delivered to each strip using either an earthen ditch and siphon tubes, gated pipe, or underground piping and above ground valves. Usually, other than that in the borders, all the soil surface in the strip comes in contact with the irrigation water, unlike the furrow method.

During an irrigation, a relatively large flow of water is directed into each strip. The time it takes for the water to reach the end of the field is the advance rate. When the water is somewhere between 60 to 90 percent of the way down the strip, the water is shut off, and the water already in the strip continues to move down the strip. The time it takes for the water to recede from the soil surface (from the top of the strip to the bottom) is the recession rate. To achieve a high DU, the advance rate must be very similar to the recession rate, which results in a uniform IOT over the strip. Generally, a border-strip system is designed and operated to have a small amount of tailwater, which requires a tailwater recovery system for reducing applied water. Border-strip systems are designed to have a high DU and can achieve a high SAE, but only for a specific AD. Border-strip systems are well suited to crops with a constant deep root zone, such as alfalfa, pasture, trees, and vines. Technologies and actions for border-strip systems to optimize DUs and increase SAEs include:

(1) Modify the advance rate to match the recession rate by either increasing or decreasing the onflow rate, changing border spacing, and using laser leveling to achieve a uniform slope and minimize cross slope.

(2) Use a properly planned and designed tailwater recovery system, and use the captured tailwater efficiently on the same field or on other irrigated fields. Tailwater recovery is essential to optimizing SAE.

Level Basin systems can be used on alfalfa, pasture, trees, vines, and various field crops. The size of each basin is variable and the design is dependent upon the infiltration rate of the soil in the basin, and the flow of water available for the basin. Basins can vary from small (50 x 50 feet) to very large (10 or more acres). There should be little or no slope within a basin. Earthen berms are built up on all sides of the basin. Water is delivered into each basin from pipelines and valves (for smaller basins) or from lined or unlined ditches with large gates. Normally, level basins are designed to have no tailwater. However, they can be designed to have an outflow, for the situation where too much water was applied. To achieve a high DU, the basin must be level, the flow of water must be high enough to cover the soil surface in a very short time (without any soil erosion from the flow), and the soils must be very uniform within the basin. Technologies and actions to optimize DUs and increase SAEs for level basin systems are outlined below:

(1) Use laser leveling to achieve a precise grade.

(2) Minimize soil variability within a basin. Large basins can be redesigned into smaller basins, each with more uniform soil characteristics.

Pressurized (Piped) Irrigation Systems. These systems use pipelines and water emission devices (connected to the pipelines) to discharge water into the field and onto (or under) the soil surface. Water is pressurized using a pump, usually passes through a filter to reduce the chance of clogging the emission devices, and is fed into a main pipeline system to sub-mains, which feed water to lateral pipelines (with the emission devices attached) in the cropped field. The water flowing from the devices is in the form of either a spray or a very small continuous stream. As the water meets the soil, the water infiltrates the soil to replenish soil moisture.

Pressurized systems are very different from surface systems. The performance of surface systems is dependent upon soil infiltration rates, IOT, and the amount of water applied. With pressurized systems, the DU is constant and depends on the design of the hardware. The DU will not change, unless pipeline leaks or clogging of devices occur or winds distort the spray pattern. Pressurized systems can apply water at a constant DU, and can apply almost any amount of water during an irrigation. One of the most important design considerations for achieving high DUs is pressure regulation. Almost all pressurized emission devices have a flow rate that changes with pressure. More pressure means a higher flow, a lower pressure means a lower flow. Excessive pressure variations in the design will result in a low DU.

The most important considerations for achieving high SAE with pressurized systems are applying the correct amount of water during an irrigation, and maintaining a high DU. Since a pressurized system can apply any amount of water with the same uniformity, the amount of water that is needed to replenish the crop root zone must be determined before the irrigation. Then the irrigation can be operated for the correct amount of time to apply the required water. The major types of pressure irrigation systems used in California -- sprinkler and micro-irrigation -- are discussed in the following paragraphs.

Sprinkler systems are the most common type of pressurized systems and can be used for almost all crops. With sprinkler systems, the emission devices are sprinkler heads, which create a spray that falls on the soil surface where it infiltrates into the soil. There are many different sprinkler head designs with flow rates that can vary from 10 gallons per minute to less than 1 gallon per minute. The spacing of the sprinkler heads in the field is dependent upon the flow rates and the radius of the area where the spray contacts the soil. To achieve high DUs, systems are designed to space sprinkler heads close enough so that there is the proper amount of overlap of their wetted areas.

There are two main considerations for achieving high DUs. A system must be designed to have a minimal pressure variation, which ensures uniform flow rates from the sprinkler heads. The sprinkler nozzles must be maintained, because clogged or partially clogged nozzles lower DU, and worn nozzles will change flow rates, resulting in larger variations in pressure in the system, and reducing DU.

To achieve high SAEs, the correct amount of water needs to be applied during an irrigation. Also, the application rate, which is the rate (in inches per hour) at which the spray falls onto the soil sloping, must be the same or less than the soil's infiltration rate. This latter point is especially important in fields, because the applied water would begin to puddle and flow over the surface and off the field. There are many variations in sprinkler systems used in California. Following are most commonly used types:

(1) Permanent systems use underground pipelines. Risers connect to an underground lateral usually with a sprinkler head attached less than a foot from the surface. These systems are commonly used for orchard irrigation (under tree), but with taller risers, are used for vines.

(2) Solid set systems are those that use above ground aluminum pipelines, usually in 20 to 30 foot sections. Short risers connect the aluminum laterals to the sprinkler heads. With solid set system, the irrigation system covers a complete field. The system stays in the field for the whole growing season, and is removed before harvest. These systems are used mainly for field and truck crops.

(3) Hand move systems are similar to the solid set systems, using the same aluminum pipelines, but do not normally cover a whole field. After an irrigation, the sprinkler laterals are disconnected from the submains, and moved by hand to the next location in the field. After each irrigation, the laterals are systematically moved to the next location. These systems are usually designed for each part of the field to receive irrigation water every 7 to 14 days. These systems are used on field crops, truck crops, and orchards.

(4) Wheeled systems have the lateral, risers, and sprinkler heads all mounted on wheels that can be moved throughout the field during the irrigation season. Side roll systems are designed to be stationary during the irrigation. After the irrigation, they are moved (using an on-board engine or by hand) to the next location.

(5) Linear move systems have the lateral, risers, and sprinklers mounted on large wheeled towers. The system continuously travels down the field during irrigations. The water is usually supplied to the system using a canal parallel to the travel of the system.

☞Photo: Center Pivot or Linear Move Sprinkler System

(6) Center pivot systems are similar in structure to linear move systems, except instead of the lateral traveling down the field, it travels in a circle in the field. One end of the lateral is fixed in the middle of the field, where the water enters the lateral. The entire lateral rotates around this pivot, and is continuously moving during irrigations.

Technologies and actions for sprinkler systems to optimize DUs and increase SAEs are outlined below:

(1) Ensure that pressure variation within the system is minimized and that sprinkler heads, nozzles, and spacings are adequate for the proper amount of overlap in spray. Ensure that application rates are lower than the soil infiltration rate, and that filtration is adequate for the system. The sprinkler system must be designed properly, and must be properly maintained.

(2) To avoid spray losses, avoid irrigation during windy conditions, and ensure pressures and nozzles are compatible to avoid misting (excessively small droplet size).

(3) Where appropriate, use flow control nozzles.

Micro-Irrigation (Low volume) systems were first used in California in the 1970s and their use increases each year. Low volume systems have many of the same components of sprinkler systems: source of pressurized water, filter, main pipelines, sub-mains, and laterals. The main difference is in the devices that emit the water to the soil. These emit water at a very low flow rate (from 0.5 to 10 gallons per hour). There are two type of devices used, drip and micro-spray. With drip devices (emitters), the water flows out as a constant stream (0.5 to 2 gallons per hour) directly to the soil, whereas with micro-spray, the devices (spray heads) produce a spray (4 to 20 gallons per hour) over the soil surface. Among differences from sprinkler systems are that usually the entire main and sub-main pipelines are underground rigid plastic pipe, the laterals are flexible plastic hose, and the filtration devices are designed to filter much smaller particles to prevent clogging. Emitter and spray heads use small orifices, channels, or nozzles to regulate the low flow rates, and thus are more subject to clogging by particulate matter and biological growth.

Drip systems use emitters that are usually spaced 2 to 5 feet apart (closer spacings are possible with drop type). Drip systems can either be buried or placed on the soil surface. Because the water is not spread over the soil surface (as in a surface or sprinkler system) the soil directly underneath the emitters becomes wet, and the water moves both laterally and downward in the soil. As a result, the wetted area under the soil surface is somewhat spherical, with a wetted radius of up to 3 feet. Emitter spacing is based upon the soil type being irrigated, with sandier soils needing a closer spacing, and clay soils using the farthest spacing. Drip systems are mostly used in orchards and vines, strawberries, and nurseries.

Micro-spray systems use small plastic sprinklers or jets that spray water over the soil surface, creating a wetted area up to 12 feet or more in diameter or more. The droplet sizes are small compared to a sprinkler system, and the application rate is also low. Micro-spray heads are connected to the plastic lateral hoses, usually one hose per row of trees. These systems are not designed to wet the entire soil surface like a typical sprinkler system. These systems are used almost exclusively in orchards.

Both drip and micro-spray systems can achieve high DUs if pressure variation is minimized. Because of the small nozzles and emitter pathways, partial or full clogging is always a potential problem, and can significantly reduce DU. These systems require regular maintenance to reduce clogging, including frequent flushing of pipelines and lateral hoses, and addition of chemicals (such as chlorine and acids) to kill bacteria and other life forms that can grow in the hoses and emitters and to reduce scale buildup. The systems require filtration, and the filters need regular maintenance to ensure that they operate as designed.

Achieving a high SAE with these systems is dependent on maintaining a high DU, and on proper irrigation scheduling. One advantage to these systems is that they are more easily controlled than most sprinkler and surface systems. They can be started and stopped easily (providing the water delivery system can accommodate rapid starting and stopping of flow), and are easier to automate, even to the extent of using remotely sensed field information for making irrigation timing decisions. Technologies and actions for optimizing DUs and increasing SAEs of micro-irrigation systems are outlined below:

(1) Ensure that pressure variation within the system is minimized, the filtration system is adequate, and prevent emitter clogging.

(2) Perform regular inspections of filters, emitters/spray heads, pressure levels, and tubing/pipelines, and provide regular maintenance, including filter cleaning and hose/pipeline flushing.

Irrigation Scheduling. All irrigation systems require proper irrigation scheduling (the determination of timing of irrigation and the amount to be applied) to achieve high IE. Scheduling is a decision made by the grower, using information from various sources. To develop an optimized irrigation schedule, the grower must consider several factors: allowable or desirable crop water stress, the water holding capacity of the soil within the crop's root zone, water availability and/or delivery constraints, amount of effective rainfall, and application rate.

With this information, along with soil moisture determinations, plant stress indices, and/or estimates of crop evapotranspiration, a grower can develop a water budget schedule. The water budget monitors how much water is leaving the soil (evapotranspiration), in order to make a decision to irrigate when the soil moisture reaches to a predetermined point (allowable depletion), and to operate the irrigation system for the correct amount of time to refill the moisture in the crop's root zone.

Soil Moisture. Soil moisture status can be monitored many ways. Subsurface soil samples can be taken and visually inspected to estimate the moisture status. Tensiometers can be used. Tensiometers are plastic tubes with a ceramic porous cup at the bottom and a cap and a vacuum gauge at the top. Tensiometers are installed in the soil, porous cup down, at different depths (usually 1 to 4 feet). When filled with water, the tensiometer gives a gauge reading in centibars, between 0 (wet) and 100 (dry). The readings are recorded, and when graphed, provide important information on when to irrigate. Moisture content can be estimated from electrical resistance devices (such as gypsum blocks) that rely on the change in electrical conductivity of water in the device. The devices are buried beneath the soil surface, with the wires protruding at the surface, and using a meter connected to the wires, the resistance is measured and recorded. Neutron probes are another moisture-sensing device. A probe measures the amount of neutrons reflected from water molecules in the soil. These readings can be used with a calibration curve to estimate the soil water content.

Plant Moisture. Plant stress indicator devices include pressure bombs and infrared thermometers. A pressure bomb is used to determine the turgor pressure within the cells of a plant's leaf. A leaf is taken off a plant and the petiole is inserted into a small hole in a rubber stopper. The leaf is put into the device's pressure chamber with the end of the leaf stem exposed. Pressurized nitrogen enters the chamber slowly while the end of the stem is observed. When a fluid begins to emerge from the stem end, the pressure reading is recorded. This pressure is an estimate of the turgor pressure within the leaf, and indicates of the moisture status of the plant.

Infrared thermometers are hand-held devices used to measure plant canopy temperature. Plants can control water loss by regulating the stomatal openings in their leaves. With the stomata closed, less water is evaporated and the leaf temperature rises. The difference between the plant canopy temperature and the ambient air temperature, with adjustments for humidity and wind, provides a measure of plant stress. Monitoring temperatures with this device aids in determining if crop stress is occurring, and can be an indication of the status of soil moisture.

Estimating ET. Evapotranspiration estimates of crops are developed using either evaporation pans or weather information. Class A evaporation pans are commonly used for measuring evaporation. The pans, constructed of galvanized steel or aluminum, are four feet in diameter and 10 inches tall. Pans are situated in the center of a large irrigated turf area. The pan station includes devices to measure rainfall, temperature, wind speed, and relative humidity. Evaporation is measured by monitoring the change in height of the water in the pan. The evaporation readings are multiplied by crop coefficients to estimate evapotranspiration of a specific crop.

☞Photo: Evaporation Pan

Many growers use automated weather station data for determining crop evapotranspiration, such as the California Irrigation Management Information System. CIMIS is a repository of climatological data collected at over 80 computerized weather stations located throughout the State. CIMIS was developed by DWR and the University of California at Davis. Weather data are collected daily from each weather station site and automatically transmitted to a central computer located in Sacramento. The weather data (solar radiation, temperature, relative humidity, and wind speed) are used with a modified Penman equation to calculate reference evapotranspiration, ET_o. ET_o is the estimate of evapotranspiration of well-watered 4 to 6 inch tall turf. ET_o is used in a grower's irrigation scheduling to estimate crop evapotranspiration, by multiplying ET_o by the appropriate crop coefficient.

Reducing Crop ET. Regulated deficit irrigation is a technique to reduce crop evapotranspiration. Irrigation is reduced during a specific stage of the crop's growth, resulting in some crop stress at the time, but with little or no negative effects on production, quality, or on future growth. Research has shown that this management technique may be applied to some tree crops such as pistachios, almonds, and olives. This irrigation strategy may have its greatest value in drought situations, where a grower may have to underirrigate.

Summary - Agricultural Technologies. Growers will continue to optimize and improve their operations, including irrigation, as new technologies become available that have potential benefits. To further reduce applied water above what could be achieved with available technology, DU would have to increase above 80 percent. Increasing DUs in gravity surface systems becomes more difficult at higher DU values. It is cost-effective and not difficult to improve DU from 50 percent to 70 percent with any system. Moving above 80 percent may not be attainable, due mainly to variability in soil infiltration rates. Achieving DUs up to 90 percent would probably be possible only with micro irrigation systems and good irrigation management.

Emitters and spray heads will probably be improved, including designs having higher levels of pressure compensation capabilities. Research will be done to determine what chemicals could be effectively used to inhibit emitter clogging. There will be more use of computer controlled systems, to monitor weather, soil moisture, crop moisture status, irrigation system leaks, and system pressures. These advanced irrigation systems are most likely to be adopted for high value crops (e.g., strawberries and wine grapes).

There is potential for more use of existing low-energy precision application systems. LEPA is a traveling system similar to a linear move sprinkler system, except that instead of sprinklers, it has drop tubes from the lateral down to the soil surface. These systems are used in fields that have furrows with small checks or dams in the furrow about 3 to 5 feet apart. The LEPA travels perpendicularly to the furrows, and the drop tubes emit water uniformly into the furrows.

Water Supply Treatment Technologies

Description of Water Treatment Technologies

Water supplies from water recycling, groundwater recovery and desalting are becoming a larger component of potential future supplies, especially in urban areas. These water supply options rely on the basic water treatment technologies described below. Following a description of the technologies, their application to specific options, such as treating contaminated groundwater and desalting, are described.

Activated Carbon Adsorption. Treatment by activated carbon adsorption is most applicable to organic contaminants. By bringing the contaminated water in contact with activated carbon in either granular or powdered form, the contaminants are adsorbed onto the carbon. The process may be accomplished by batch, column, or fluidized-bed operations. Spent carbon may be regenerated or may be disposed of in accordance with regulatory requirements. In addition to the traditional use of activated carbon in taste and odor control and dechlorination, carbon adsorption is widely used for removal of volatile organic chemicals and synthetic organic chemicals.

Granular Activated Carbon. Granular activated carbon adsorption is a unit process with a proven ability to remove a broad spectrum of organic chemicals from water. EPA considers GAC adsorption as the best available technology for removal of VOCs and SOCs.

Powdered Activated Carbon. PAC has traditionally been used to control taste and odor in water, and is also used for removal of certain SOCs, especially pesticides. PAC, in combination with conventional water treatment technology, can provide acceptable levels of pesticide removal in surface waters. A typical application of PAC would be for seasonal removal of pesticides found in municipal treatment plant raw water supplies during wet weather. Some limitations to the use of PAC include the potential need for large doses of carbon to achieve the desired levels of treatment, and the resultant high sludge production.

Air-stripping. This treatment technique removes volatile organic compounds from contaminated water. Countercurrent air-stripping in a packed tower is the most common process. The conventional configuration of a unit consists of a tower with water inflow at the top and air inflow at the bottom. The tower is filled with small diameter random packing. As clean air moves upward, the VOCs transfer from the water phase into the air phase. Treated water exits from the bottom, and air-containing VOCs is discharged from the top of the tower, either into the atmosphere or into a gas treatment system.

☞Photo: Air Stripping Tower

Since the air-stripping process transfers contaminants from one phase (aqueous) to another (gaseous), air-stripping projects must take into consideration the allowable emissions of VOCs . In some parts of the State, such as the South Coast Air Quality Management District, such emissions are strictly regulated, and additional treatment (see below) to reduce emissions to acceptable levels will be needed. Granular activated carbon adsorption may be used with air-stripping to control emissions from the packed-tower aeration system.

The closed-loop air-stripping process is an innovation to the traditional air-stripping treatment. The closed-loop air-stripping process combines air-stripping with an ultraviolet photo-oxidation process, destroying the VOCs and thereby controlling emission. In this process, the exhaust air from the PTA unit is irradiated with UV light in a photo-oxidation chamber, and the VOCs are destroyed. The end products are carbon dioxide, hydrochloric acid, and ozone. The treated air is recycled to the PTA unit.

Advanced Oxidation Process. Unlike GAC or air-stripping, where contaminants are transferred from one medium to another, advanced oxidation processes can destroy organic contaminants. Examples of AOPs include treatment with ultraviolet radiation, ozone/hydrogen peroxide, and ozone/UV. AOPs provide more powerful oxidation and at faster rates than conventional oxidants such as chlorine. As a result, they can remove compounds which have not been treatable with conventional oxidants. These oxidants can also reduce disinfection by-products created by processes such as chlorination. To date, much AOP work has focused on removing low-molecular weight solvents such as TCE and PCE that are found as contaminants in groundwater by-products, and on reduction of DBPs.

Membrane Technologies. Membrane technologies include reverse osmosis, electrodialysis, micro filtration, ultrafiltration, and nanofiltration. RO, MF, UF, and NF are pressure-driven processes of barrier separation; electrodialysis employs electrical potential as the driving force. Membrane processes have been used for desalting, removal of dissolved organic materials, softening, liquid-solid separation, pathogens removal, and heavy metals removal. Another group of promising membrane technologies is the membrane phase-contact processes. These processes are not pressure driven but remove contaminants by extraction into another phase, like air-stripping and solvent extraction. Applications include membrane air-stripping of volatile organics, and denitrification using microporous membrane immobilized biofilm to selectively remove nitrate ions from water.

Reverse Osmosis. This process uses specially prepared membranes which permit water to flow through the membrane while rejecting the passage of dissolved contaminants. This is based on the natural osmotic process where water passes through a semipermeable membrane from a solution of higher concentration to a lower one. In reverse osmosis, a pressure greater than osmotic pressure is applied to the contaminated water. Water passes through the membrane but the contaminants are retained. RO systems using newer membranes operate at about 250 psi for desalting brackish groundwater to 1,000 psi for seawater desalting.

Electrodialysis. This electrically driven technology induces contaminant ions to migrate through a membrane, removing them from the water solution. In an electrodialysis unit contaminated water is pumped into narrow compartments, separated by alternating cation-exchange and anion-exchange membranes, selectively permeable to positive and negative ions. A variation of this process is called electrodialysis reversal. In electrodialysis, the electrical current flow is always in the same direction. In EDR, the electrical polarity is periodically reversed. This results in the reversal of ion movement and flushes scale-forming ions from the membrane surfaces.

Microfiltration, Ultrafiltration, and Nanofiltration. These technologies operate comparably to reverse osmosis, but at lower pressures. More stringent regulations in drinking water coupled with diminishing sources of pristine waters, have stimulated interest in the use of membrane technologies in drinking water treatment. The use of low-pressure membrane filtration for municipal water treatment is a relatively new concept in the water industry, which has traditionally used membranes for removing salts or organic materials. MF operates at pressures ranging from 20 to 100 psi and is capable of removing micron-sized (10^{-6} m) materials. Colloidal species are physically rejected by MF membranes. UF operates at pressures ranging from 3 to 150 psi and is capable of removing materials that are in the order of a nanometer in size (10^{-9} m) or larger from water. Dissolved inorganic contaminants are not retained by MF and UF membranes. One of the most novel applications of low-pressure membrane technology is the removal of microorganisms such as total coliform bacteria, viruses, *giardia,* and *cryptosporidium* from drinking water sources without using chemicals for primary disinfection. The efficiency of low-pressure membranes in removing particles from untreated water supplies has been well documented. MF and UF have shown to be capable of consistently reducing turbidities to <0.1 NTU, regardless of the influent turbidity level. NF operates at pressures ranging from 150 to 300 psi and has characteristics between those of RO and MF. NF membranes are often considered to be "loose" RO membranes. The capital cost of an NF plant is typically high compared with conventional treatment processes because of the cost of membranes and high-pressure equipment. Pilot and bench-scale studies have demonstrated that nanofiltration is effective in removing disinfection by-product organic precursors and synthetic organic chemicals such as pesticides. Nanofiltration is also frequently used for water softening applications.

Ion-Exchange Process. The process passes contaminated water through a packed bed of anion or cation resins. The resin type is selected based on the contaminant to be removed. The treatment process exchanges ions between the resin bed and contaminated water. By displacing the ions in the resin, the contaminant ions become part of the resin and are removed from the process water. During the ion-exchange process, the exchange capacity of the resin becomes depleted and needs regeneration to become effective. Sodium chloride brine is used to regenerate the resin. Ion-exchange is widely used for removing nitrates in groundwater and for removal of some metals. Currently, its effectiveness in removing radionuclides is being investigated in a number of full scale applications.

Chemical Precipitation. Chemical precipitation is used for removing heavy metals from water. The contaminants are precipitated from solution and removed by settling. There are several types of chemical addition systems including: the carbonate system, the hydroxide system, and the sulfide system. The carbonate system relies on the use of soda ash and pH adjustment. The hydroxide system is most widely used for removing inorganics and metals. The system responds to pH adjustment, and uses either lime or sodium hydroxide to adjust the pH upward. The sulfide system removes most inorganics (except arsenic) because of the low solubility of sulfide compounds. The disadvantage is that sulfide sludges are susceptible to oxidation to sulfate when exposed to air, resulting in resolubilization of the contaminants.

Biological Treatment. Biological treatment is a technique that uses microorganisms to remove contaminants in water through metabolic processes. The process can be a suspended growth system where the microorganisms and nutrients are introduced in an aeration basin as suspended material in a water-based solution, or a fixed-film system where the microorganisms attach to a medium which provides inert support. Biological treatment is used in domestic wastewater treatment and is applied to the treatment of water contaminated with organic compounds, such as petroleum hydrocarbons. Biological treatment is often used for remediation of leaking fuel tank sites, either above ground, or in situ.

Disinfection. This treatment inactivates pathogenic organisms in water. The common disinfection process is chlorination, often used to treat wastewater and drinking water. Two relatively new disinfection processes applied in wastewater reclamation include ultraviolet radiation and ozonation. Ultraviolet radiation has recently been approved by the Department of Health Services for use in disinfecting recycled water. UV has been shown to be as effective as chlorine or ozone in reducing coliform bacteria and is more effective at virus removal. Ultraviolet radiation has the potential to be more cost effective than chlorine disinfection, and eliminates the disinfection byproducts and handling hazards associated with chlorination. Ozonation offers another alternative to chlorination of water.

Innovative Treatment Technologies. Many of these innovative technologies are being used in remediation of hazardous waste sites, for treating contaminated groundwater. Combining basic technologies with a few innovative techniques are characteristics of these technologies. In the future, use of such technologies may see broader application in groundwater recovery projects. Some examples of technologies, primarily those applied at pilot or full scales, are covered here.

EnviroMetal Process. This proprietary technology treats groundwater using reactive metal (usually iron) to enhance the abiotic degradation of dissolved halogenated organic compounds. A permeable treatment wall of the coarse-grained reactive metallic media is installed across the plume, breaking down the contaminants as they migrate through the aquifer. This technology has received regulatory approval for use in at least two industrial facilities in California, for treating shallow plumes with elevated levels of volatile organic compounds.

Integrated Vapor Extraction and Steam Vacuum Stripping. This technology removes volatile organic chemicals, including chlorinated hydrocarbons, in groundwater and soil. The integrated system has a vacuum countercurrent stripping tower that uses low-pressure steam to treat contaminated groundwater, and a soil vapor extraction process to treat the soil. The stripper and the soil vapor extraction systems share a granulated carbon unit to decontaminate the combined vapors. The technology has been used to treat trichloroethylene contaminated groundwater and soil at Lockheed Aeronautical Systems in Burbank.

In Situ Steam-Enhanced Extraction . This technology uses injection wells to force steam through the soil to enhance vapor and liquid extraction thermally. The process extracts volatile and semivolatile organic compounds from contaminated soil and groundwater. The recovered contaminants are condensed or trapped by activated carbon filters. After treatment is complete, subsurface conditions are excellent for biodegradation.

Subsurface Volatilization and Ventilation System. This technology uses a network of injection and extraction wells to treat subsurface organic contamination through soil vapor extraction and in situ biodegradation. A vacuum pump extracts vapors while an air compressor injects air in the subsurface. In most sites, extraction wells are placed above the water table and injection wells are placed below the groundwater level. Because it provides oxygen to the subsurface, the process can enhance in situ bioremediation.

PACT Wastewater Treatment System. Zimpro Environmental, Inc. developed this proprietary technology combining biological treatment and powdered activated carbon adsorption to achieve treatment of contaminated water. Live microorganisms and PAC contact wastewater in the aeration tank. The biomass removes biodegradable organic contaminants, while PAC enhances adsorption of organic compounds. PACT systems treating up to 53 mgd of wastewater are in operation. This process is applicable to groundwater contamination from hazardous waste sites.

Capacitive Deionization. The development of carbon aerogel electrodes has created new interest in using capacitative deionization for desalting applications. The technology offers the potential for reducing the cost of desalting applications.

The CDI desalting process is an experimental process being researched at Lawrence Livermore National Laboratory. It involves passing water through a stack of electrodes made of carbon aerogel and generating a small voltage differential, approximately one volt, between alternating positive and negative electrodes, thus drawing ions out of the solution. The ions are removed by electrostatic attraction and are retained on the electrode until the polarity is reversed. The ions are then captured with a small amount of water. Other dissolved materials such as trace metals and suspended colloids are removed by electrodeposition and electrophoresis.

For the past two years, the process has been operating in a laboratory. NaCl, $NaNO_3$, and NH_4ClO_4 solutions have been tested with excellent results. Electrode life has been successful in the laboratory with electrodes operating for more than two years with little degradation. The electrodes appear to be regenerable with little loss of capability. Energy requirements appear less than current desalting technologies. Field testing has begun in Northern California, and will later be moved to Southern California.

Applications of Water Treatment Technologies

Wastewater Reclamation. Reclamation and reuse applications include agricultural irrigation, groundwater recharge, landscape irrigation, wildlife habitat enhancement, industrial use, and recreational impoundments. Agricultural irrigation, groundwater recharge and landscape irrigation constitute the greatest use of reclaimed water in the State. Additionally, a proposed project in San Diego would use reclaimed water for indirect potable reuse (see sidebar).

San Diego Water Repurification Program

The city of San Diego, in conjunction with the San Diego County Water Authority, is proposing to reclaim 15,700 af per year of wastewater for potable purposes. Results of the pilot studies conducted by the agencies show that wastewater can be repurified to a level suitable for human consumption. Under this proposal, the agencies would construct an 18-mgd wastewater repurification facility using state-of-the-art technology to treat reclaimed water from the city of San Diego's North City Water Reclamation Plant. The repurified water would be transported over 20 miles to the San Vicente Reservoir, where it would be blended with imported raw water supplies and stored for a period of time. The blended water would eventually be conveyed via the existing El Monte Pipeline to the city's Alvarado Filtration Plant for traditional treatment before being delivered to the city's drinking water system.

☞ Photo: San Vicente Reservoir

Repurified water is based on a concept of multiple barriers. Reclaimed water, effluent from the North City Water Reclamation Plant which has been treated to levels acceptable for landscape irrigation and for other nondrinking purposes, will be treated further at the proposed 20-mgd wastewater repurification facility. The repurification process includes subjecting the reclaimed water to four more treatment processes including low-pressure filtration, reverse osmosis, ion-exchange, and ozone treatment. These treatment processes, while redundant in their functions, ensure the reliability of the overall repurification system and produce an end product that exceeds current health and safety standards.

The pilot studies show that from both a technological and an operational perspective, the city of San Diego could turn reclaimed water into an alternative source of drinking water. The city is preparing an environmental document and has begun design of the project. The project is expected to begin operation in late 2001.

Criteria for Indirect Potable Reuse

The California Potable Reuse Committee was formed in 1993 to look into the viability and safety of reuse. The committee, commissioned by the Department of Health Services and DWR, developed six criteria that must be met before indirect potable reuse is allowed. These are:

(1) Application of the best available technology in advanced wastewater treatment with the treatment plant meeting operating criteria. BAT must include a membrane component with the functional equivalency of reverse osmosis.

(2) Maintenance of appropriate reservoir retention times based on reservoir dynamics.

(3) Maintenance of advanced wastewater treatment plant reliability to meet consistently primary microbiological, chemical and physical drinking water standards.

(4) Compliance of surface water augmentation projects using advanced treated reclaimed water with applicable State criteria for groundwater recharge for direct injection with reclaimed water.

(5) Maintenance of reservoir water quality. In addition to meeting drinking water standards, recycled water used for reservoir augmentation shall be of equal or better quality than that in the storage reservoir on a constituent-by-constituent basis.

(6) Provision for an effective source control program. The source control program is to include pretreatment/pollution prevention measures that prohibit the discharge of any substance which, whether alone or in combination with other wastewater constituents, causes or threatens malfunction or interference with the wastewater treatment process, constitutes a hazard to human health or safety or affects the water quality of the potable storage reservoir.

Treatment criteria for reuse of municipal wastewater are mandated in Title 22 of the California Code of Regulations. These criteria specify the treatment level for specific reuse applications. Treatment technologies used for reclaiming wastewater depend on the reuse application. For most nonpotable reuse applications at least secondary treatment is required. To achieve secondary treatment, conventional biological treatment processes are used such as activated sludge process, trickling filters, and oxidation ponds, followed by sedimentation, and disinfection with chlorine.

Tertiary treatment is often standard for recycled water. Tertiary treatment is achieved by adding a filtration step after secondary treatment, and before final disinfection. Two major types of filtration technology are applied in tertiary treatment plants: conventional and direct filtration. Conventional filtration, as defined in Title 22, includes coagulation, sedimentation and filtration to condition the water. Conventional filtration technology requires that the filters be backwashed to prevent turbidity breakthroughs. The backwash requirements with Title 22 requirements result in an equipment-intensive process. Direct filtration provides a cost effective and convenient tertiary technology when secondary effluent quality is high. The technology will likely be incorporated in areas where effluent from residential areas provides the process water. Newer water recycling facilities use direct filtration as part of the tertiary treatment process. Direct filtration bypasses the sedimentation step. Continuously backwashed direct filtration technology is available, minimizing equipment needs.

The ability to achieve the maximum use of tertiary treated water for landscape irrigation and other outdoor applications hinges on the ability to store the treated water supply when it is not needed. Landscape irrigation demands, for example, have a wide seasonal variation in the State's inland areas. An aquifer storage and recovery approach may be a cost-effective solution to the storage needs. ASR stores recycled water in a slightly depleted aquifer during the winter and withdraws the stored water in the summer. Because significant groundwater recharge is intentionally avoided, ASR can be used by agencies that produce tertiary treated water, but do not invest in the additional nutrient removal steps required for groundwater recharge. When successful, ASR allows the storage of relatively large quantities of recycled water without the capital cost investment associated with above-ground reservoirs. Other treatment technologies recently used for enhanced treatment include the use of chemical precipitation, carbon adsorption, reverse osmosis, micro filtration and ultrafiltration, radiation and ozonation. Advanced treatment (treatment beyond the tertiary level) allows additional removal of pathogens, nutrients, trace metals, organics and total dissolved solids.

Table 5-2, taken from SWRCB data, is an example of reclamation plants having a capacity of at least 10 mgd. (As of the date of this Bulletin, there are several additional plants of this size now under construction, but not yet in operation.)

Table 5-2. Reclamation Plants with a Capacity of at least 10 mgd

Name	Capacity (mgd)	Treatment Process	Type Of Reuse	Annual Use (acre-feet)
San Jose Creek Water Reclamation Plant (Los Angeles County Sanitation District)	100	Primary Sedimentation, Activated Sludge, Coagulation, Filtration and Chlorination	Groundwater recharge, agricultural and landscape irrigation, and nursery stock irrigation	15,400
Fresno-Clovis Metropolitan Area Regional Wastewater Facilities	60	Primary Sedimentation, trickling filter and activated sludge	Agricultural Irrigation	13,700
Donald C. Tillman Water Reclamation Plant (city of Los Angeles)	40	Activated sludge, coagulation, filtration, chlorination, and dechlorination	Recreational lake and landscape irrigation	2,802
Los Coyotes Water Reclamation Plant (Los Angeles County Sanitation District)	37	Primary sedimentation, activated sludge, coagulation, filtration, and chlorination	Landscape irrigation, industrial reuse such as process water, concrete mix and dust control, and crop irrigation	4,500
Chino Basin Municipal Water District Regional Plant No. 1	32	Activated sludge, coagulation, filtration, chlorination, and dechlorination	Landscape irrigation and recreational lakes	1,700
Long Beach Water Reclamation Plant	25	Primary Sedimentation, activated sludge, coagulation, filtration and disinfection	Landscape irrigation, nursery irrigation, and repressurization of oil-bearing strata	3,000
city of Modesto Wastewater Quality Control Facility	25	Primary sedimentation, trickling filter, oxidation ponds, and chlorination	Fodder crop irrigation	14,400
city of Bakersfield Wastewater Treatment Plant No. 2	19	Primary sedimentation and oxidation ponds	Crop irrigation	16,800
Laguna Treatment Plant (city of Santa Rosa)	18	Primary sedimentation, activated sludge, coagulation, filtration and chlorination	Fodder irrigation	9,300
Fairfield-Suisun Subregional Wastewater Treatment Plant	17	Activated sludge, coagulation, filtration, chlorination, and dechlorination	Sod farming and maintenance of hunting marsh	2,400
Michelson Water Reclamation Plant (Irvine Ranch Water District)	17	Primary sedimentation, activated sludge, coagulation, filtration, and chlorination	Landscape irrigation, nursery irrigation, and toilet flushing	8,200
Whittier Narrows Water Reclamation Plant (Los Angeles County Sanitation District)	15	Primary sedimentation, activated sludge, coagulation, filtration, and chlorination	Groundwater recharge and nursery stock watering	10,100

Table 5-2. Reclamation Plants with a Capacity of at least 10 mgd

Name	*Capacity (mgd)*	*Treatment Process*	*Type Of Reuse*	*Annual Use (acre-feet)*
Pomona Water Reclamation Plant (Los Angeles County Sanitation District)	13	Primary sedimentation, activated sludge, coagulation, filtration, and chlorination	Agricultural irrigation landscape irrigation, and industrial process	8,000
city of Visalia Water Conservation Plant	12	Primary sedimentation, trickling filter, activated sludge, and chlorination	Non-food crop irrigation	4,900
Valley Sanitary District Wastewater Treatment Facility (Riverside County)	12	Primary sedimentation, trickling filter, activated sludge, and oxidation ponds	Non-food crop irrigation	4,300
Desert Water Agency Wastewater Reclamation Facility (Riverside County)	10	Coagulation, filtration, and chlorination	Landscape irrigation	2,700
Water Factory 21 (Orange County Water District)	10	Coagulation, filtration, carbon adsorption, and reverse osmosis	Groundwater injection for intrusion barrier	2,600
Lancaster Water Reclamation Plant	10	Primary sedimentation, oxidation ponds, and chlorination	Wildlife refuge and fodder irrigation	9,700

As advanced tertiary treatment becomes feasible and cost effective, and as public acceptance increases, recycling highly treated wastewater for potable use may become a reality (see sidebar). Recycled water is presently used for recharge of groundwater supplies. Reservoir retention is an important element in potable reuse projects. The reservoir acts as an additional barrier in the treatment process by providing pathogen removal capability, and by providing a buffer to identify and respond to possible failures at the treatment plant. Surface water supply augmentation projects would require site-specific pilot studies and permit criteria.

Water Reclamation

Desalting. According to the International Desalting Association's inventory of worldwide desalting plants, the United States is second in usage of desalting in the world with almost 1 maf per year of installed capacity. In 1985, the United States had less than 7 percent of the world's capacity. In 1993, that figure rose to nearly 15 percent. Only Saudi Arabia has more installed capacity. Desalting is increasingly used in California. Common feedwater sources for desalting plants include brackish groundwater, municipal or industrial wastewater and seawater. Costs of desalting increase with increasing feed water salinity.

Reverse Osmosis. Membrane and related technologies will have the most impact on California. Currently, reverse osmosis accounts for 89 percent of the installed capacity of desalting plants in California, including all the significant plants supplying municipal water supplies or reclaiming municipal waste water. Reverse osmosis is likely to continue to dominate in California, in light of recent significant improvements in membrane performance.

Reverse osmosis membranes have changed significantly in the last 20 years. Membranes are available to serve many purposes. This allows water suppliers to select and operate membranes specifically suited to the feed water quality and the required product water quality. Reverse osmosis membranes have developed into two principal classes.

The first class is the traditional reverse osmosis membrane which rejects all salt ions (as well as other dissolved constituents) equally. This process is also called hyperfiltration, used on water requiring the removal of all classes of dissolved constituents.

The second class of reverse osmosis membrane processes is called nanofiltration. Nanofiltration membranes reject larger dissolved ions such as calcium and sulfate, along with equally large dissolved constituents of a feed water. For example, when used in a water softening role, they will remove calcium, magnesium, and sulfate from water, but allow sodium and chloride ions to pass through. In parts of Florida groundwater is hard and contains organics in undesirable concentrations. Nanofiltration membranes are often used to soften the water and remove the organics. Because this is the most popular use of these membranes, nanofiltration is often referred to as "membrane softening."

Table 5-3. Reverse Osmosis Membranes 1970-1995

Year	Operating Pressure (psi)	Flow Rate (gpd/element)	Salt Rejection
1970	600	375	97%
1990	225	1,800	97%
1995	150	2,600	99%

Advancements in membrane technology have reduced operating pressures, increased flow rates, and increased salt rejection in typical reverse osmosis applications -- thereby reducing treatment costs (see Table 5-3). Energy requirements have accounted for at least 50 percent or more of the operating costs of a reverse osmosis plant. As operating pressures have decreased, so have energy costs. New membrane materials have allowed more membrane area per module and higher productivity per square foot. Increased productivity of membranes and their longer life expectancy reduces capital cost of the plant, reducing the cost of water. Increasing salt rejection provides better water quality. In the case of groundwater desalting, the high purity product water can be blended with raw water to meet the desired overall product water quality. Again, the cost is reduced by having a smaller desalting plant.

Marina Coast Water District

☞ Photo of Marina Coast Plant

The Marina Coast Water District is the primary water supplier for the city of Marina, which is eight miles northeast of Monterey in Monterey County. The MCWD relies on the Salinas Valley groundwater basin as its primary water supply source, as do other Salinas Valley urban and agricultural water suppliers. As a result of groundwater extractions throughout the Salinas Valley, the groundwater basin is in an overdraft condition. Overdraft of the Salinas basin has caused seawater from Monterey Bay to migrate into two of the three aquifers underlying the coastal part of Salinas Valley. Seawater intrusion has rendered some groundwater unfit for use. MCWD has had to replace shallower wells with deeper wells to meet customer demands for potable water.

MCWD has investigated ways to diversify its water supply sources because of the potential groundwater extraction limitations. In 1992, the district completed a desalting feasibility study as part of its investigations.

MCWD's project involves constructing and operating a reverse osmosis seawater desalting plant. This plant will produce approximately 300,000 gpd of potable water, and will use beach wells for seawater intake and brine disposal. A shallow production well drilled into the beach deposits near MCWD's water treatment plant provides intake water for the desalting plant. Using a beach well to supply seawater to the project minimizes the need for extensive pretreatment. The beach sands will filter most of the suspended material in the seawater. A subsurface feedwater pipeline conveys saline feedwater to the desalting plant where the reverse osmosis membranes will desalt the seawater. The reverse osmosis system is a single stage system operated at 40 to 45 percent recovery rates. It will take about 750,000 gpd of seawater to produce about 300,000 gpd of potable water. The water produced by this method would then be conveyed into an existing potable water pipeline.

Brine is a desalting by-product, and this project will produce a reject brine flow of about 450,000 gpd. An injection well in the shallow dune sand aquifer will be used to dispose of the brine, where it will migrate toward the ocean and be diluted by natural groundwater and wave action. Power requirements for the desalting plant are estimated at 5,000 kilowatt-hours of electricity per acre-foot of water produced, or about 15 kWh for each 1,000 gallons of desalted water. The total electrical usage is estimated at 1,500 megawatt-hours per year for 300 af of water produced. Total project fixed costs for the desalting plant are estimated at about $2.8 million.

Treatment of Contaminated Groundwater. Pesticides and other agricultural chemicals, industrial solvents, heavy metals, nitrates, and organic and inorganic chemicals have been found in California's groundwater. Many groundwater contamination sites -- such as those associated with leaking underground tanks or with most manufacturing operations -- are small-scale and seldom affect water supplies on a regional basis. These small sites may require cessation of pumping from one or two-water supply wells, or the installation of wellhead treatment on the wells. Of greater water supply concern are areas of regional groundwater contamination that significantly affect local agency water supply opportunities.

The selection of technologies for treating groundwater contamination depends on site conditions and the contaminants to be removed. Although there are a variety of options, no one technology is necessarily capable of responding to all conditions found at a groundwater contamination site. In practice, treatment technologies are sometimes used in combination to remediate contamination. For example, groundwater contaminated with nitrates and pesticides requires ion-exchange technology to remove the nitrates and GAC adsorption to remove the pesticides.

Table 5-4 provides some examples of wellhead treatment sites. The capacity of the treatment units at the locations shown ranges from 0.3 mgd to 4.1 mgd.

Table 5-4. Wellhead Treatment Sites Examples

Location	*Contamination*	*Treatment*
Lodi	DBCP	GAC
Lodi	Pathogens	Ultraviolet
Modesto	DBCP	GAC
Modesto	Nitrates	Electrodialysis
Fresno	DBCP	GAC
Fresno	TCE	Air-Stripping
Clovis	DBCP	GAC
Monrovia	TCE	Air-stripping
Monrovia	VOCs	Air-Stripping
San Gabriel Valley	VOCs	GAC

Some local agencies have integrated their groundwater treatment plants into their municipal distribution systems. The West Basin Municipal Water District for example, constructed a 1.5 mgd facility that uses reverse osmosis technology to remove elevated levels of dissolved solids from contaminated groundwater. The plant supplies about 1,500 af annually of recovered groundwater to the District for municipal use and to Dominguez Water Corporation for industrial and municipal uses.

The Glenwood Nitrate Water Reclamation Project is a 3.7 mgd ion-exchange treatment plant that treats nitrate-contaminated groundwater. The plant is in La Crescenta, and is owned and operated by Crescenta Valley County Water District. Treated groundwater from the plant is sold to Foothill Municipal Water District and Metropolitan Water District of Southern California for municipal and industrial uses. The plant's eventual project yield will be about 1,600 af annually.

The city of Pomona owns and operates a 15 mgd ion-exchange treatment plant. The plant, built in 1992, is the second largest ion-exchange treatment plant in the world. The plant treats nitrate-contaminated groundwater from the Chino Groundwater Basin. At full capacity, the treatment plant supplies approximately 70 percent of the city's municipal water demand.

McFarland Nitrate Contamination

McFarland is an incorporated city of 7,650 people in Kern County. Much of McFarland's economy is based on agriculture and on related industries. The McFarland Mutual Water Company supplies municipal water. The company depends on groundwater for raw water supply and has four active wells.

Elevated levels of nitrates in the water from MMWC were detected in the early 1960s. Many of the wells sampled showed levels of nitrate exceeding the drinking water standard of 45 mg/liter-NO_3. Studies identified fertilizer application on agricultural lands as a major contributor to nitrates in the groundwater. MMWC abandoned two of its wells as a result of nitrate contamination and provided treatment for two wells to reduce the nitrate levels to meet drinking water standards. Two replacement wells were constructed at deeper levels to extract groundwater free of nitrate or pesticide contamination.

In 1978, the MMWC requested and received a grant from EPA to study groundwater treatment alternatives. The results led to the 1983 design and construction of a 1 mgd ion-exchange treatment plant, which led to the 1987 construction of a second 1 mgd ion-exchange treatment plant for a second well. Today, both wells supply about 18 af annually of treated water to the city of McFarland and adjoining rural areas within the MMWC service area.

The technology used in the mechanical design and planning for the plants relies heavily on practices used in the water softening industry. The chemical process design is based on research of anion exchange resins completed under the EPA grant. Plant location was dictated by the already-in-place wells and distribution systems. Because of a lack of a centralized distribution system, the plants had to be designed to operate from a single well. Well pumps operate on a demand basis, so the plant had to be able to operate automatically. The system was designed to accept water directly from the well, treat for nitrate removal, and allow treated water to flow directly into the distribution system. The ability of the process to adapt to quick start-up and frequent on-off operation was an important consideration in choosing this process over reverse osmosis and biological treatment methods.

Some groundwater aquifers in California are contaminated because of past hazardous waste disposal practices. A number of these sites are undergoing remediation. Carbon adsorption, membrane filtration, air stripping, advanced oxidation processes, biological treatment, chemical precipitation, and innovative treatment technologies are examples of technologies used.

For example, Aerojet General Corporation's manufacturing facility in Rancho Cordova operates a 6.5 mgd groundwater treatment facility which removes volatile organic contaminants in the groundwater. The treatment facility has air-stripping towers and GAC adsorption units.

Treated groundwater is reinjected into the aquifer through wells, and is also recharged via surface impoundments. Another example is the Valley Wood Treating Company in Turlock, which uses pump-and-treat and *in situ* treatment techniques for chromium-contaminated groundwater. The company pumps groundwater and uses chemical precipitation for first stage contaminant removal. Next, a reducing agent is added to the treated water, which is then reinjected into the aquifer. The resulting reaction allows for *in situ* reduction of the chromium and subsequent fixation of residual chromium in the soil.

Case History: McClellan Air Force Base Groundwater Contamination

In 1981, McClellan AFB initiated soil and groundwater investigation at its Sacramento site, as part of a Department of Defense program to identify and evaluate suspected contamination at Air Force installations nationwide. Groundwater contaminants identified included volatile organics such as TCE and vinyl chloride, semivolatile organics, petroleum hydrocarbons, and trace heavy metals. Subsequent investigations revealed that contaminants had migrated off the base. At least one municipal well was abandoned because of contamination. In 1986 and 1987, 500 homes with private domestic wells to the west of the base were connected to the city of Sacramento's water system.

In 1987, groundwater extraction and on site treatment began. The treatment involved an air stripper, with incineration and caustic scrubbing of the air stream, followed by carbon adsorption and biological treatment of the effluent. The treatment plant had a capacity of 1.44 mgd and discharged its treated water to Magpie Creek and to a wetland area on the west side of the base under permits from the Central Valley Regional Water Quality Control Board. Later, the biological treatment unit was removed after the concentration of ketones was low enough to be removed by the air stripper and carbon adsorption units.

In September 1996, the air stripper and incinerator were replaced with an ultraviolet/ hydrogen peroxide system to remove volatile organics. The GAC is still in use. Operating and maintaining the UVOX system is less expensive than the air-stripping and incinerating process, and the treatment efficiency of the UVOX reduces carbon use in the GAC units. Several more years of extraction and treatment of the groundwater will be required before the contaminated aquifer is restored to usable quality.

Case History: Occidental Chemical Agricultural Products, Inc.

DBCP Contamination. In the late 1970s, pesticide and fertilizer contamination was discovered in soil and groundwater underlying and adjacent to the Occidental Chemical Agricultural Products, Inc., manufacturing facility near the city of Lathrop. The primary contaminants found were dibromochloropropane, ethylene dibromide, and sulfolane. OxyChem removed or capped contaminated soil at the facility in 1981 and 1982. The groundwater remediation program began operation in 1982 and continues today. The original groundwater restoration system was designed to remove DBCP and EDB to 1 part per billion concentration. It consisted of five extraction wells, a 500 gpm granular activated carbon adsorption treatment system, and two injection wells for deep well disposal of treated groundwater into an unusable confined aquifer. Sulfolane was not removed from the groundwater, but its injection to the aquifer was considered acceptable since the aquifer was designated unusable for domestic or agricultural purposes. The 1988 State Water Resources Control Board Resolution No. 88-63, which designated all surface and groundwater of the State as suitable or potentially suitable for municipal or domestic water supply, a 1989 EPA revision of the maximum contaminant levels for DBCP and EDB, and a 1989 DHS health-based maximum allowable level for sulfolane in municipal water resulted in more stringent treatment standards for groundwater at the OxyChem facility. In 1992, OxyChem made operational changes in the treatment system and added a biological treatment system (microbial inoculation of the carbon treatment system) to remove sulfolane from the groundwater to comply with the new treatment standards of 0.2 ppb DBCP, 0.02 ppb EDB and 57 ppb sulfolane. Two extraction wells were added, increasing the treatment capacity to 600 gpm.

The groundwater restoration system was designed to remove the contaminated groundwater and to control the hydraulic gradient in order to prevent off-site migration of the contaminants. Several dozen monitoring wells were built to monitor the effectiveness of the system. These monitoring reports have shown reductions of contaminant concentrations and control of contaminant plume. However, it is estimated that groundwater remediation will need to be continued for a significant time.

Inflatable Dams

Inflatable rubber, or fabric and rubber, dams and tubes have been used for years as weirs to impound water, or as protection devices. Their use, however, is becoming more popular. Alameda County recently installed an air inflatable dam in the Alameda Creek Flood Control Channel to divert water to ground water recharge quarry pits. A similar water inflatable dam has been used in the Russian River at Mirabel since 1976, where water is diverted to percolation ponds. The San Gabriel and Los Angeles river basins also have similar devices. In these cases, the inflatable dam is attached to a reinforced concrete sill constructed across the channel.

P.G.&E added an inflatable dam to the crest of its Pit No. 3 Dam on the Pit River to replace flash boards that had to be installed and removed by hand.

During the flood of January 1997, an inflatable rubberized berm was installed on the water side of the Sutter Bypass levee to provide additional height needed to protect the levee from overtopping. Rubber berms of this type are used as coffer dams during construction projects in wet environments, or as pollution containment devices.

☞ Photo: Alameda Co. Inflatable Dam

Environmental Water Use Technologies

Refuge Irrigation Management

Detention of Floodwater. Opportunities for water conservation in wetland management include emphasizing the development of seasonal wetlands, which use water available during the winter when it is not needed for crop production. Wetlands near rivers with relatively small flood control storage reservoirs could temporarily store some floodwaters that might otherwise cause erosion or sedimentation problems in areas downstream. Recent proposals have been made in the San Joaquin Basin to degrade existing levees to permit flood waters to overflow former private lands now managed as refuges. Detention on the refuges would offer water quality benefits by removing sediments and other contaminants, while offering flood management benefits of stage reduction. Some water applied to wetlands for flood control purposes would recharge groundwater and support wetland vegetation. This could help meet wetland water demand, which would otherwise compete for stored water.

Adaptive management of cropland. Recent investigations of winter flooding of rice fields have shown the technique helps break down crop residues. Flooded rice fields attract waterfowl during the winter migration period. The waterfowl activity accelerates physical and microbial degradation of crop residues, reducing cultivation costs to disk under the residue, as well as public health concerns about burning the residue.

Remediation of drain water. Wetland plants have been found to remove selenium from water applied to them. One mechanism of removal may involve bacteria and fungi in the root zone receiving carbon-containing compounds from the plants while providing mineral nutrients including selenium to the plants. Currently, University of California, Berkeley, researchers are experimenting in the Tulare Lake Drainage District with a variety of wetland plants irrigated with high-selenium drain water in flow-through wetland cells. Careful management of such facilities to remove selenium while avoiding food chain concentrations may result in developing safe operating criteria for wetlands supplied with drain water. This would permit significant wetland acreage in the Tulare Lake Basin to be supported with drain water. (Drain water not used to support wetlands would still have to be disposed of through other means, such as evaporation pools.)

Real-Time Water Quality Management

The San Joaquin River is a major hydrologic contributor to the Delta, and at times is the dominant environmental influence on the Delta. In 1990, AB 3603 authorized establishment of the San Joaquin River Management Program, established an advisory council, and mandated that the council identify the problems facing the river system and further, prepare a plan that would identify solutions to improve, restore and enhance currently degraded conditions. A final plan was prepared and distributed in 1995, identifying almost 80 actions that could significantly improve conditions in the San Joaquin River system. One of those action items was a real-time water quality monitoring network.

The San Joaquin River real-time water quality monitoring network is a tool that enables interested parties to make informed water management decisions in the San Joaquin River Basin. The network is comprised of water quality and quantity instrumentation, as well as a computer model that forecasts water flow and quality along the lower San Joaquin River. The network relies on a collaborative approach that encourages river stakeholders to voluntarily reduce water quality impacts on one another, and is expected to improve average water quality in the San Joaquin River.

The program that manages the real-time network is composed of three main activities: data collection and processing, data analyses, and data dissemination. The primary objective of the program is to operate and maintain the network to improve water management for water quality, water supply, and fisheries in the lower SJR basin. Additionally, flood protection interests will benefit by having real-time flow information available to help predict SJR stages. One goal of real-time management is to meet SJR water quality objectives more frequently, enabling water managers to use high-quality releases made specifically for meeting SJR water quality objectives (for example, releases from New Melones Reservoir) more efficiently.

A demonstration of the capabilities and benefits of real-time management has recently been concluded. The demonstration project (1) expanded the number of sites providing real-time stage and water quality data, (2) developed analytical tools to collect and process real-time data, and (3) disseminated weekly forecasts of daily SJR flow and salinity at Vernalis since February 1996. The project also established an operational system featuring a custom graphical user interface with Internet upload and download capabilities.

Fish Screen Technologies

State of the Art. Fish screens are being installed on water diversions as a means to protect fish from potential entrainment losses. A properly designed fish screen, with appropriate instream flows, allows diversions to occur when juvenile fish may be present, without causing unacceptable fish losses. Screened diversions allow a more reliable water supply throughout the year.

The National Marine Fisheries Service and the California Department of Fish and Game have mandates for the installation and operation of fish screens. If a new diversion is installed, significantly modified, or other changes are made to an existing intake site, a new fish screen is usually required. The Department of Fish and Game has established a priority based list of diversions that should be screened based on the potential impact on fish losses. Protecting the most significant diversions first will help achieve fish protection goals with the available financial resources. Programs to financially assist diverters in the installation of such screens are available through the CVP Improvement Act's Anadromous Fish Screen Program, CALFED's ecosystem restoration program, the Natural Resources Conservation Service, and various provisions of Proposition 204.

The current fish screen technology is based on criteria established by NMFS and DFG. Physical screens combined with low approach velocities, and proper cleaning systems can effectively protect fish greater than about one-inch long. Conventional screens will not protect smaller or larval-sized fish which may be present at some sites for limited durations.

Smaller pumped diversions (slant or vertical pump installations on a river with flows less than 40 cfs) generally use bolt-on screens available from a variety of manufacturers. These screens are similar to those used to reduce the debris in sprinkler irrigation systems. Depending on the site and the system, screens may be made of corrosion resistant woven wire, perforated plate or wedge-wire material (well screen). These materials can be formed into cylindrical shapes or flat plate panels and designed into the intake system.

Since 1994, with the availability of public funding assistance, there has been an increase in the number of sites with these screens. Examples include installations at the Pelgar-Mutual Water District, Anderson-Cottonwood Irrigation District, Maxwell Irrigation District, and others (See Figure 5-1.)

Figure 5-1. Fish Screen Installations Map

Larger diversion sites are screened with low approach positive velocity barrier screens, but are more complex facilities. These intake screens may include significant civil works and are often off the main river channels where they must provide fish handling and bypass systems. These facilities require more attention to hydraulic conditions than smaller intake screens.

Several recently constructed facilities have been designed to current regulatory criteria for screening, including screens at the M&T Ranch Diversion on the Sacramento River near Chico, the Parrot-Phelan diversion on Butte Creek, and the Tehama-Colusa Irrigation District canal rotary drum screens.

☞Photo: of Parrot-Phelan Screened Diversion.

Several large facilities are nearing the final phases of design or construction. They include diversions on the upper Sacramento River at the Glenn-Colusa Irrigation District near Hamilton City (3,000 cfs capacity), Reclamation District 108 near Grimes, Reclamation District 1004 near Princeton, the Princeton Irrigation District/Cordura-Glenn Irrigation District/Provident Irrigation District consolidated diversion, and others.

Current Research. There is significant research and experience in fish screen technology. The technology has responded to a number of factors including ESA requirements in the Northwest and in California for the protection of salmonids, FERC relicensing requirements, and the heightened awareness of fish losses at diversions.

Research can be broken down into two categories: (1) positive barrier technologies, and (2) behavioral barrier technologies. Although physical screens are considered state of the art, and are acceptable to the resource agencies, behavioral barriers have been demonstrated to deter fish from being dragged at some sites, and may offer enhanced fish protection at even physically screened sites.

Positive Barrier Technologies. Several significant applied research projects are underway. A research pumping plant has been constructed at the USBR's Red Bluff Diversion Dam to divert Sacramento River water into the Tehama-Colusa Canal. This facility (see photo, Chapter 2) was developed to provide water to the Tehama-Colusa Canal when the diversion dam gates must be raised for fish passage. The research pumping plant is testing centrifugal and Archimedes screw pump technologies to evaluate their impacts on fish. The research plant and the biological evaluations of its effectiveness now being carried out are providing significant data on the potential application of these technologies to other sites.

Since the early 1950s, fish screen velocity criteria have been developed for juvenile salmon and a few other anadromous species. Little is known about the screening requirements for resident Bay-Delta species (such as smelt) which require protection. Through a cooperative interagency program effort, a large circular screened testing flume has been constructed at U.C. Davis to investigate fish performance and behaviors under various hydraulic conditions. This research will improve our understanding of the needs of fish and help design more effective screens.

Screen cleaning and proper operations and maintenance are essential for the reliability of diversion and fish protection. In the last 10 years, cleaning technologies have advanced in response to possible zebra mussel invasions and clogging from aquatic weeds. To combat the problem combinations of hydraulic and air backwash systems, improved horizontal and vertical brush cleaners, and automated controls are used. Screen materials and coatings have also been developed to prevent biofouling. Some investigations underway include USBR's Tracy Pumping Plant Fish Facility Improvement Program, Contra Costa Water District's new Los Vaqueros and proposed Rock Slough fish screens and an investigation of air cleaning systems by the USBR.

Higher velocity fish screens, which reduce exposure to the screen surface, are being studied. These systems are potentially less expensive because of the reduced screen area required. Modular systems are being developed creating a more universal application. Advancements in automation and control systems are being used to regulate screens' hydraulics and operations. These advancements provide better fish protection and diversion reliability.

Behavioral Barrier Technologies. Technological advances in underwater acoustic and electrical systems have spurred a renewed interest in the investigation of sound and electricity in fish guidance systems. In the past, these systems have had limited success affecting fish behavior. Some guidance and protection have been observed, but the systems cannot achieve the level of protection desired by State and federal resource agencies. Fish responses to behavioral technologies are variable since they may respond to other environmental stimuli, including hydraulic conditions, temperature, predator avoidance and lighting conditions. Behavioral systems are attractive in some cases because physical structures may not be viable, or are cost-prohibitive for the expected benefit.

In California's Central Valley, several behavioral barrier demonstration projects have been investigated. Brief summaries are below:

(1) Georgiana Slough Acoustic Barrier. Juvenile salmon survival has been shown to improve significantly if salmon are allowed to remain in the Sacramento River rather than being drawn into the central Delta via Georgiana Slough. Physical barriers and screens have been considered at this site, but are not feasible because of hydraulic conditions, water quality, recreational uses and adult fish migration issues. A behavioral system is being studied which would improve fish survival by guiding the fish away from the hydraulic influence of Georgiana Slough. Twenty-one underwater acoustic speakers have been installed at the natural flow split on the Sacramento River to the Slough below the town of Walnut Grove. Studies in 1993, 1994 and 1996 showed improved guidance during low flows, but mixed results at higher flow conditions. Results have been encouraging enough to continue investigations at this site under low flow conditions. Adverse effects of acoustic system operation have not been observed.

(2) Reclamation District 108 Acoustic and Electrical Barrier Investigations. Mandated by a biological opinion, this major Sacramento River water user (700 cfs diversion capacity) near Grimes tested acoustic and electrical barriers to see if these technologies could reduce fish losses. From 1993 until 1996, tests were conducted at the site with mixed results. The acoustic system was suspended from the surface and operated on an on/off cycle to show its effectiveness. The electrical array was mounted to an underwater louver array and was similarly evaluated. Since neither system achieved the required reduction in fish entrainment, the District is constructing a positive barrier fish screen.

(3) Reclamation District 1004 Acoustic Barrier Tests. A similar acoustic barrier was installed at RD 1004's diversion on the Sacramento River near the town of Princeton. From 1994 to 1995, the system was evaluated and found to have marginal benefits. RD 1004 is installing a 360 cfs positive barrier fish screen at its diversion site.

(4) Behavioral Research at Other Sites. The use of low frequency "infrasound" systems and the use of lighting systems (strobe lights) is under investigation at several sites outside of

California. Many of these systems are being tested and used with other screening technologies to improve their effectiveness in difficult hydraulic environments.

Temperature Control Technology

Temperature control technology can be used to manage the temperature of releases for fishery purposes. During summer months reservoir temperature gradients result in warmer water near the surface of the reservoir, with cooler water occurring near the bottom. Two types of temperature control devices are currently being used in northern California reservoirs: outlets that permit temperature selective releases, such as USBR's Shasta Dam TCD, and temperature control curtains, such as those at Whiskeytown and Lewiston Reservoirs.

Temperature Control Device. USBR completed the Shasta Dam TCD in May 1997, and is currently fixing leakage problems that affect operation of the device. The structural steel shutter device is 250 feet wide by 300 feet high and encloses all five penstock intakes on the dam. The shutters allow for selective withdrawal of water, depending on the downstream temperature needs of the salmon. Prior to installation of the structure, USBR has bypassed the Shasta powerplant to provide water of adequate temperature for downstream fish at a cost of over $32 million dollars in lost power revenues. Installation of the Shasta TCD will provide USBR with the flexibility to provide optimal water temperature downstream for salmon, as well as allowing hydropower generation.

Temperature Control Curtain. Curtains can permit selective withdrawal of water at intake or outlet structures, to provide desired temperatures for salmonids and other aquatic species, resulting in the ability to conserve water for other uses. Four temperature control curtains have been installed by the USBR, two in Lewiston Reservoir (in 1992), and two in Whiskeytown Reservoir (in 1993). These curtains are constructed of Hypalon, a strong, rubberized nylon fabric. They are supported in the water column by steel tank floats, and anchored to stay in place.

At Lewiston Reservoir, an 830-foot long, 35-foot deep curtain is suspended from flotation tanks and is secured by a cable and anchor system. This curtain was designed to block warm surface water from entering into the Clear Creek Tunnel Intake. As a result, cold water from the bottom of the reservoir is diverted into Whiskeytown Reservoir. A second curtain was installed around the Lewiston Fish Hatchery intake structure to allow warmer or colder water, depending on the season, to be taken into the hatchery. This curtain, 300-foot long by 45-feet deep was designed to either skim warmer water or underdraw cooler water, depending on whether the curtain was in a sunken or floating position.

Ideally, cold water diverted from Lewiston is to be routed through the Whiskeytown's hypolimnion (deep, cold water layer) into the Spring Creek Conduit intake. To accomplish this, two curtains were installed: (1) a tailrace curtain downstream at Carr Powerplant and (2) an intake curtain surrounding the Spring Creek Conduit intake. The tailrace curtain (600-foot-long and 40-foot-deep) was installed to force cold water from Carr Powerplant into Whiskeytown's hypolimnion with a limited amount of mixing with the epilimnion (warm surface water). This curtain acts to restrain the warm surface water from moving upstream towards Carr Powerplant. With the tailrace curtain in-place mixing is reduced where the density current plunges into the hypolimnion upstream of the tailrace curtain. The second curtain, a 2,400-foot-long, 100-foot-deep, surface-suspended curtain surrounds the Spring Creek Conduit intake. This curtain, like the Lewiston curtain, was designed to retain warm surface water while allowing only cold water withdrawal.

The results of the use of the temperature curtains at both Lewiston and Whiskeytown Reservoirs is about a 5° F temperature decrease from the Trinity River to the Sacramento River. USBR believes this decrease to be significant, making the temperature curtains a successful tool for conserving reservoir releases.

Costs of the temperature control curtains generally run about $1,000 per foot for the smaller ones. The largest curtain at Whiskeytown Reservoir cost about $1.8 million. The expected duration of use is about 10 years before replacement may be required. To date, not one of the 4 curtains in place at these two reservoirs has needed major repairs.

A number of studies are ongoing to better refine the curtains use for temperature control, such as operations and locations, as well as ensuring that no adverse impacts result to biological resources in the reservoirs where they are installed.

Weather Modification

Since the early 1950s, California has widely practiced cloud seeding to augment precipitation, mostly along the western slopes of the Sierra Nevada and along the coast ranges. In 1996, there were 14 active cloud seeding programs operating in California. The goal of all these cloud seeding programs is to increase water supply for agricultural and municipal uses, and for hydroelectric power generation.

The principal elements of cloud seeding operations include selection of cloud masses, seeding materials, and methods to dispense the agents within the clouds. There are several classes of seeding agents available. Seeding agents are introduced into the clouds either by using ground-based generators or by aerial delivery systems.

Precipitation from clouds is a result of two different processes or mechanisms. The first is coalescence, whereby tiny cloud droplets collide to form larger droplets until the larger droplets eventually fall out as rain. The collision and coalescence process works at temperatures above freezing. The second mechanism requires ice particles, and occurs at subfreezing temperatures. Many clouds have supercooled water droplets sometimes at temperatures far below freezing. Ice particles can grow rapidly in this environment at the expense of the liquid droplets. Eventually the ice particles fall as snow which will change to rain if the lower levels of the atmosphere are above freezing. Enhancing either of the two processes of precipitation formation can lead to more efficiency in producing rain or snow from a cloud. Some natural clouds appear to be deficient in ice forming nuclei; those clouds offer an opportunity to assist the rainmaking process.

Seeding Agents

Certain materials have been found effective in converting supercooled water droplets into ice crystals. Commonly used seeding agents for this purpose are silver iodide and dry ice. Some other chemicals also work including some organic compounds. Hygroscopic materials such as salt, urea, and ammonium nitrate have been used in warmer clouds to assist the coalescence process.

Dry Ice. Dry ice was frequently used in early cloud seeding programs in the United States in the 1950s and early 1960s. A switch in emphasis to the use of silver iodide occured in the mid- 1960s, probably because of more convenient storage and dispensing capabilities. Dry ice applications are limited to airborne delivery systems. Dry ice has received increased attention in recent years due to its low cost and high effectiveness.

Silver Iodide. Silver iodide has been the preferred seeding agent in the majority of cloud seeding programs in the United States. Particles of silver iodide are usually produced through some combustion process followed by rapid quenching which forms trillions of effective freezing nuclei per gram of silver iodide consumed. Cloud seeding by silver iodide can be carried out using ground-based or aerial generators.

Liquid Propane. Liquid propane is a freezing agent much like dry ice. Liquid propane has the advantage of working at higher temperatures, up to a degree or two below freezing, whereas silver iodide is not very effective when temperatures are warmer than - 5^0 C. Dispensing is limited to ground-based system because it is a flammable substance. Liquid propane sprayed into the atmosphere chills the air to temperatures well below zero degrees centigrade. As temperatures approach -40°C, water vapor in the air rapidly condenses into trillions of cloud droplets which immediately freeze and grow into tiny ice crystals. Propane is used operationally in clearing supercooled fog from airports in Alaska and the northern portion of the continental U.S.

Bacteria. *Pseudomonas syringae*, a bacterium thought to reduce frost damage in plants, has been shown to be an effective nucleating agent. Use of this bacterium as a seeding agent has been limited to producing snow in ski resorts, although there have been some experiments with aerial applications.

Seeding Delivery Systems

Aerial Application. Commonly available aircraft can be modified to carry an assortment of cloud seeding devices. Silver iodide nuclei dispensers include models which burn a solution of silver iodide and acetone and pyrotechnic dispensers. A typical silver iodide-acetone solution is forced through the nozzle into a combustion chamber where the solution is ignited, and the silver iodide crystals formed through combustion are expelled into the atmosphere. Pyrotechnics are similar to ordinary highway flares. Pyrotechnic flares impregnated with silver iodide can be mounted on aircrafts, burned, and dropped into the clouds. Dry ice is frequently dispensed through openings through the floor of aircraft modified for cloud seeding. Types of aircrafts used in operational cloud seeding programs range from a single engine aircraft to larger twin engine aircraft.

Ground Applications. The most common type of ground generator in use consists of a solution tank which holds the seeding agent. Other components include a means of pressurizing the solution chamber, dispensing nozzles, and a combustion chamber. Frequently, such systems employ a propane tank with a pressure reduction regulator to pressurize the solution tank, as well as to provide as a combustible material into which the silver iodide-acetone solution is sprayed. Other systems utilize nitrogen to pressure the solution tank that directly burns the seeding agent solution. Pyrotechnics are also used at surface sites. Ground generation systems have been developed which are operated manually or by remote control.

Effectiveness

Although precise evaluations of the amount of water produced are difficult and expensive to determine, estimates range from 2 to 15 percent increase in annual precipitation, depending on the number and type of storms seeded. In 1992, both the American Meteorological Society and the World Meteorological Organization issued policy statements cautiously supportive of the effectiveness of weather modification efforts under the proper circumstances.

Chapter 6. Evaluating Options From a Statewide Perspective

A main objective of this *California Water Plan* update is the development of a conceptual water management plan (at an appraisal level of detail) to illustrate how California's water supply reliability needs could be met through the year 2020. This chapter outlines the process used to put together the conceptual plan, and evaluates water management options that are statewide in scope. A brief discussion of methods available to local agencies for financing water management options is also provided.

The planning process includes developing regional water management plans for each of the State's ten major hydrologic regions, and integrating those plans with statewide water management options to form a plan for the entire State. Development of regional water management plans is covered in Chapters 7 through 9.

Statewide water management options include demand management or reduction measures that many water agencies are expected to implement, and large-scale water supply augmentation measures that would provide supply to multiple beneficiaries (usually in more than one hydrologic region). For example, a large north-of-Delta offstream storage reservoir studied under CALFED's Bay-Delta program is considered a statewide option. On the other hand, a small reservoir project being studied by a local agency to provide benefits only to its service area is not a statewide option. Such local projects are covered in Chapters 7 through 9 in the regional water management plans.

The Bulletin 160-98 Planning Process

The process used to prepare a conceptual water management plan for California draws upon, at an appraisal level of detail, techniques of integrated resources planning. IRP evaluates water management options -- both demand management options and supply augmentation options -- against a fixed set of criteria and ranks the options based on costs and other factors. Although the IRP process includes economic evaluations, it also incorporates environmental, institutional, and social considerations which cannot be expressed easily in monetary terms.

The development of regional water management plans uses information prepared by local agencies. The regional water management plans are not intended to replace local planning efforts, but to complement them, by showing the relationships among regional water supplies and water needs and the statewide perspective. Local water management options form the basis of regional plans which are combined into the statewide plan. Figure 6-1 shows the hydrologic regions for which plans are prepared.

The major steps involved in the Bulletin 160-98 water management options evaluation process included:

- Identify water demands and existing water supplies on a regional basis.
- Compile comprehensive lists of regional and statewide water management options.
- Use initial evaluation criteria to either retain or defer options from further evaluation. For options retained for further evaluation, some were grouped by categories and others were evaluated individually.
- Identify characteristics of options or option categories, including costs, potential demand reduction or supply augmentation, environmental considerations and significant institutional issues.
- Evaluate each regional option or category of options in light of identified regional characteristics using criteria established for this Bulletin. If local agencies have performed their own evaluation, review and compare their evaluation criteria with those used for the Bulletin.
- Evaluate statewide water management options.
- Develop regional water management plans.
- Develop a statewide plan by integrating the regional plans.

The first step in developing the regional water plan is to prepare water budgets for the study areas to identify the magnitude of potential water shortages for average and drought year conditions. In addition to identifying shortages, other water supply reliability issues in the region are identified. Once the shortages are identified, a list of local water management options is prepared. Where possible, basic characteristics of these options (e.g., yields, cost data, significant environmental or institutional concerns, etc.) are identified.

Figure 6-1. Hydrologic Regions of California

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After the options are identified, they are compared with the initial screening criteria shown in the sidebar. For options deferred from further evaluation, the major reasons for deferral are given (e.g., high economic costs, significant environmental impacts to threatened and endangered species, lack of data). Options retained for further evaluation are placed into the following categories:

- Conservation (urban and agricultural)
- Modifications to existing reservoirs/operations
- New reservoirs/conveyance facilities
- Groundwater/conjunctive use
- Water transfers/banking/exchange
- Water recycling
- Desalination (brackish groundwater and seawater)
- Other local projects (e.g., weather modification)
- Statewide (e.g., CALFED, SWP, DWB)

Because each of these categories may contain many individual options, some options within each category were further combined into groups based upon their estimated costs. (For example, water recycling projects costing less than $500/af were grouped into one category.) Options were evaluated and scored against the set of fixed criteria shown in the sidebar on evaluation criteria.

Initial Screening Criteria

The criteria used for initial screening of water management options were:

- **Engineering**--an option was deferred from further evaluation if it was heavily dependent on the development of technologies not currently in use, it used inappropriate technologies given the regional characteristics (e.g., desalination in the North Lahontan region), or it did not provide new water (e.g., water recycling in the Central Valley).
- **Economic**--an option was deferred from further evaluation if its cost estimates (including environmental mitigation costs) were extraordinarily high given the region's characteristics.
- **Environmental**--an option was deferred from further evaluation if it had potential significant unmitigable environmental impacts or involved use of waterways designated as wild and scenic.
- **Institutional/Legal**--an option was deferred from further evaluation if it had potentially unresolvable water rights conflicts or conflicts with existing statutes.
- **Social/Third party**--an option was deferred from further evaluation if it had extraordinary socioeconomic impacts, either in the water source or water use areas.
- **Health**--an option was deferred from further evaluation if it would violate current health regulations or would pose significant health threats.

Options Category Evaluation

Evaluation Criteria	*What is Measured?*	*How is it Measured?*	*Score*
Engineering	Engineering feasibility	Increase score for greater reliance upon current technologies	0 - 4
	Operational flexibility	Increase score for operational flexibility with existing facilities and/or other options	0 - 4
	Drought year supply	Increase score for greater drought year yield/reliability	0 - 4
	Implementation date	Increase score for earlier implementation date	0 - 4
	Water quality limitations	Increase score for fewer water quality constraints	0 - 4
Engineering Score			**0 - 4**
Economics	Project financial feasibility	Increase score for lower overall costs and the ability to finance	0 - 4
	Project costs/af yield	Increase score for lower overall costs/af yield (including mitigation costs)	0 - 4
Economics Score			**0 - 4**
Environmental	Environmental risk	Increase score for least amount of environmental risk	0 - 4
	Irreversible commitment of resources	Increase score for least amount of irreversible commitment of resources	0 - 4
	Collective impacts	Increase score for least amount of collective impacts	0 - 4
	Proximity to environmentally sensitive resources	Increase score for little or no proximity to sensitive resources	0 - 4
Environmental Score			**0 - 4**
Institutional/ Legal	Permitting requirements	Increase score for least amount of permit requirements	0 - 4
	Adverse institutional/legal effects uponwater source areas	Increase score for least amount of adverse institutional/legal effects	0 - 4
	Adverse institutional/legal effects upon water use areas	Increase score for least amount of adverse institutional/legal effects	0 - 4
	Stakeholder consensus	Increase score for greater amount of stakeholder consensus	0 - 4
Institutional/Legal Score			**0 - 4**
Social/Third Party	Adverse third party effects upon water source areas	Increase score for least amount of adverse third party effects	0 - 4
	Adverse third party effects upon water use areas	Increase score for least amount of adverse third party effects	0 - 4
	Adverse social and community effects	Increase score for least amount of adverse social and community effects	0 - 4
Social/Third Party Score			**0 - 4**
OtherBenefits	Ability to provide benefits in addition to water supply	Increase score for environmental benefits	0 - 4
		Increase score for flood control benefits	0 - 4
		Increase score for recreation benefits	0 - 4
		Increase score for energy benefits	0 - 4
		Increase score for additional benefits	0 - 4
		Increase score for improved compliance with health and safety reguiations	0 - 4
Other Benefits Score			**0 - 4**
Total Score			**0 - 24**

The Bulletin 160-98 option evaluation process relied substantially upon locally developed information. Local agencies' methods for making estimates of options' costs vary, thus making direct comparisons between cost estimates difficult. To make costs comparable, a common approach for estimating cost per acre-foot was developed for this Bulletin. Where the information was readily available, costs of local agency projects were normalized using this approach. (However, due to time constraints and lack of detailed information for some local options, not all option costs were normalized.)

Water management options can serve purposes other than water supply (e.g., flood control, hydroelectric power generation, environmental enhancement, and recreation). For this Bulletin, cost estimates were based only on the costs associated with water supply, and the cost estimates took into account: (1) capital costs associated with the construction and implementation of the option (including any needed conveyance facilities); (2) annual operations, maintenance and replacement costs; and (3) amount and timing of deliveries. Appendix 6A describes the process used to estimate an option's cost per acre-foot.

Once options had been evaluated and scored, they were ranked according to their scores. This ranking was used to prepare the regional water management plans, taking into account options that may be mutually exclusive or could be optimized if implemented in conjunction with another other option. Depending on the characteristics of the region and the potential options, the regional water management plan may not meet all of a region's water shortages (especially in drought years), because the available options are too costly. Put another way, the economic costs of accepting shortages would be less than the costs of acquiring additional water supplies.

Water agencies may chose to accept less than 100 percent water supply reliability, especially under drought conditions, depending on the characteristics of their service areas. Shortage contingency measures, such as restrictions on residential outdoor watering or deficit irrigation for agricultural crops, can be used to help respond to temporary shortages. However, demand hardening is an important consideration in evaluating shortage contingency measures. Implementing water conservation measures such as plumbing retrofits and low water use landscaping reduces the ability of water users to achieve future drought year water savings through shortage contingency measures.

Options available to water agencies for coping with shortages that exceed the agencies' planned levels of reliability include supply augmentation actions such as purchasing water from the state Drought Water Bank, and demand reduction actions such as urban rationing or fallowing of agricultural lands. Table 6-1 summarizes actions taken by some of California's larger urban water suppliers to respond to water shortages in 1991, the driest year of the recent 1987-92 drought. Measures taken by agricultural water agencies and water users included increased pumping of groundwater, land fallowing, and intra- and interdistrict water transfers. The WaterLink system established by Westlands Water District (described in Chapter 8) is an example of an action that could be used by agricultural water suppliers to facilitate intradistrict water transfers as part of managing shortages.

The impacts of allowing planned shortages to occur in water agency service areas are necessarily site-specific, and must be evaluated by each agency on an individual basis. In urban areas where conservation measures have already been put into place to reduce applied water use by landscaping, imposing rationing or other restrictions on landscape water use can create significant impacts to homeowners, landscaping businesses, and entities that manage large turf areas such as parks and golf courses. Dry year cutbacks in the agricultural sector create economic impacts not only to individual growers and their employees, but also to local businesses that provide goods and services to the growers.

Table 6-1. 1991 Urban Water Shortage Management

		1991 Shortage Contingency Measures										
Water Agency	*Goal*	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*
Alameda County WD	18%		✔		✔		✔	✔	✔			✔
Contra Costa WD	26%	✔		✔	✔		✔	✔	✔		✔	✔
East Bay MUD	15%	✔	✔		✔	✔	✔	✔	✔			
LA Dept. of Water and Power	10%	✔	✔		✔	✔	✔	✔	✔	✔	✔	✔
MWD of Southern California	31%				✔	✔		✔				✔
MWD of Orange County	20%		✔	✔	✔	✔	✔	✔	✔	✔		✔
Orange County WD	20%			✔		✔		✔	✔			✔
San Diego Co. Water Authority	20%	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
City of San Diego WUD	20%			✔			✔	✔	✔	✔		✔
San Francisco PUC	25%	✔	✔		✔		✔	✔	✔		✔	✔
Santa Clara Valley WD	25%	✔	✔		✔			✔	✔	✔	✔	✔

A = Rationing
B = Mandatory Conservation
C = Extraordinary Voluntary Conservation
D = Increasing Rate or Surcharges
E = Economic Incentives
F = Device Distribution
G = Broadcast Public Information
H = Mailed Public Information
I = Water Patrols and Citations
J = Fines and Penalties
K = Water Transfer

Source: California Urban Water Agencies (June 1991), as cited in:
Lessons Learned from the California Drought (1987-1992), US Army Corps of Engineers, Institute for Water Resources, September 1993 (IWR Report 93-NDS-5)
Supplemented with information concerning water transfers.

Demand Management Actions

Demand-side management has taken on a key role in the management of water resources. Water conservation plays an important role in planning to meet future water demands. By making wiser use of water, the need for new sources of supply can be lessened. Many agencies have implemented programs to achieve a high level of water use efficiency.

Water Conservation

For nearly three decades, Californians have recognized the importance of water conservation. Since the 1976-77 drought, attention has focused on plans, programs, and measures to encourage more efficient use of water. The water conservation options covered in this section are in addition to implementing existing urban Best Management Practices and agricultural Efficient Water Management Practices (existing BMPs and EWMPs are discussed in Chapter 4). Since the purpose of implementing these options is to generate new water supply (by reducing existing water depletions), the conservation options evaluated in this Bulletin are limited to actions that would have the effect of creating new water supply. These options would yield additional reductions in consumptive use (depletions) above the 2020 baseline demand reduction of 2.3 million acre-feet per year resulting from statewide implementation of BMPs and EWMPs. (Reductions in depletions accrue where applied water would be lost to evapotranspiration, or to a saline water body, and could not be beneficially reused.) Quantifying consumptive use allows the comparison of water conservation options with water supply augmentation choices such as water storage or recycling facilities.

The options presented are for planning purposes only and are not mandated targets. It is an attempt to quantify the potential water savings that may be achieved by implementing measures beyond current BMPs and EWMPs. Local water agencies can evaluate these options against other available options to assess appropriate actions for their service areas.

Although water conservation options will be carried out at the local level, they are discussed here conceptually as statewide demand management options for simplicity of presentation. Analyses of water conservation options for each hydrologic region are discussed in Chapters 7, 8, and 9. The discussions below offer a statewide summary of urban, agricultural, and environmental water conservation options.

Urban Water Conservation Options

As discussed in Chapter 4, the 1991 MOU Regarding Urban Water Conservation in California commits its signatories to implementing BMPs. The baseline of future urban water use for this Bulletin was calculated from estimates of population, urban per capita water use, and conservation estimates from urban BMPs. Urban BMPs are assumed to be put into effect by 2020 in the demand analysis for this Bulletin, resulting in an estimated 1.5 maf of demand reduction statewide.

The urban water conservation options described below assume a more intensive application of current BMPs, and potential evolution of additional BMPs. If all of the options described below were implemented, nearly 800 taf per year of depletion reduction could theoretically be attained. Since little or no depletion reductions would be achieved in the Central Valley and eastern Sierra, urban water conservation options beyond BMPs are deferred for those regions.

Reduction of Outdoor Water Use. The Department's Water Conservation Office estimates that by 2020, there will be 1.5 million acres of landscape statewide being irrigated on average at about 1.0 reference evapotranspiration (ET_0), although irrigation amounts vary widely throughout the State. There are presently no firm numbers available on the acreage of statewide irrigated urban landscaping. A value of 1 million acres has been used by CUWCC members as an approximation of existing urban landscaping. For this Bulletin, based on projected increases in California's population it is assumed that irrigated landscape will increase to 1.5 million acres.

Options to reduce outdoor water use assume that landscape irrigation statewide could be reduced on average to 0.8 ET_0 in new development, and in all development. These reductions would be realized through landscape water audits and incentive programs by the retailer. So that the cost of implementing these options can be equitably compared with other supply augmentation options, we assume in the economic evaluations in Chapters 7 through 9 that implementation costs are funded by the water purveyor and not by individual homeowners. This assumption implies that water purveyors could choose to carry out landscape water management programs in much the same manner as some urban purveyors have implemented ultra low flush toilet retrofit programs.

Option 1: Reduction of Outdoor Water Use in New Development to 0.8 ET_0. The Model Landscape Ordinance indicates that a landscape plant factor of 0.8 ET_0 could be attainable through measures such as proper landscape design, more intensive landscape water audit programs, installing automatic rain sensors, and better irrigation scheduling. Statewide, about 190 taf per year of depletion reduction could be achieved by reducing outdoor water use to 0.8 ET_0 at a cost of about $750 per af. The ordinance is directly applicable to new construction; existing landscaping would require retrofitting.

Option 2: Reduction of Outdoor Water Use in New and Existing Development to 0.8 ET_0. This option extends the provisions of Option 1 to include existing development. Statewide, about 720 taf of depletion reduction could be achieved by reducing outdoor water use in new and existing development to 0.8 ET_0. The cost of this option is difficult to quantify. It is expected to be high due to the cost involved in retrofitting existing landscape.

Residential Indoor Water Use. Options to reduce indoor residential water use assume that indoor water use in the state averages 75 gallons per capita daily. Option 1 and option 2 could reduce these averages to 70 gpcd and 65 gpcd, respectively. These reduced levels of indoor water use are being met in some California communities and could be achieved statewide if strong incentive programs, such as financial incentives for retrofits, were provided. More aggressive indoor water audits are needed to assure that residential ultra low flush toilets meet these potential savings. Conversion to horizontal axis washing machines would also have to be assumed to occur in 70 percent of all residences by 2020.

Option 3: Reduce Residential Indoor Water Use to 70 gpcd. This option is based on the potential for a 2 gpcd reduction in toilet flushing, a 2 gpcd reduction in shower and faucet usage, and a 1 gpcd reduction in laundry use. These reductions result in a 7 percent reduction beyond current BMPs at the retail level. The coastal regions have, on average, achieved this level of indoor use. The Colorado River region could attain 10,000 af per year in depletion reductions at a cost of about $400 per af.

Option 4: Reduce Residential Indoor Water Use to 65 gpcd. This option is based on the potential for a 4 gpcd reduction in toilet flushing, a 4 gpcd reduction in shower and faucet usage, and a 2 gpcd reduction in laundry use. These reductions result in a 13 percent reduction beyond current BMPs at the retail level. The coastal regions have on average achieved this level of conservation. The Colorado River region could attain 20,000 af per year in depletion reductions at a cost of $600 per af.

Interior Commercial/Industrial/Institutional Water Use. Best Management Practices account for 12 to 15 percent reduction in commercial and industrial water use by 2020. Assumptions are that CII water use could be reduced an additional 15 and 20 percent beyond BMPs with aggressive audits and information programs by the retailer. These options could reduce CII water use by an additional 2 percent (15% X 15% = 2%) and 3 percent (15% X 20% = 3%). The reduction levels are based on measures with varying payback schedules, and also on a national study funded by EPA which indicates reductions of 15 to 20 percent beyond BMPs were attainable for various enterprises.

Option 5: Reduction of Interior CII Water Use by 2 percent. This option is based on measures that require a five-year start up time with payback in two years, resulting in a 15 percent reduction over BMPs by the retailer. The additional 2 percent CII reduction would require that there be increased CII water audits and compliance with existing standards and regulation. This option could achieve 34,000 af per year in depletion reductions, primarily in coastal regions, at a cost of about $500 per af.

Option 6: Reduction of Interior CII Water Use by 3 percent. This option is based on measures requiring an additional five-year start up period with a payback within two to five years, resulting in a 20 percent reduction over BMPs to the retailer. The additional 3 percent reduction would include increased CII audits and compliance with existing standards, and new efficiency standards. Forty-nine thousand af per year of depletion reduction could be achieved, primarily in the coastal regions, at a cost of $750 per af.

Distribution System Losses. The Department estimates that the average unaccounted water in the state's hydrologic regions ranges between 6 and 15 percent. Two percent is attributed to unmetered water use (including water used for construction, fire fighting, and for flushing drains and hydrants) and meter errors; therefore, distribution system losses range between 4 percent and 13 percent. Options to reduce distribution system losses assume that they could be reduced to 9 and 7 percent with more aggressive leak detection and repair programs by the retailer. This category of options will not result in any water savings in interior regions of the

State where distribution system losses recharge groundwater basins and are reused. Therefore, these options are deferred in interior regions.

Option 7: Reduction of Distribution System Losses to 9 percent. This option assumes that all leaks are repaired, that all faulty control devices are repaired, that new construction is surveyed 6 months after installation, and that leaking mains are repaired where cost effective. It is estimated that the cost of this option would be about $200 per af. The San Francisco Bay and South Coast regions are at this level of conservation. The North Coast, Central Coast, and Colorado River regions could each realize less than 1,000 af per year of depletion reductions.

Option 8: Reduction of Distribution System Losses to 7 percent. This option assumes that water system audits will be carried out every three years, leak detection surveys are conducted from the audits, and repairs are required. Distribution system losses in the South Coast region are already at 7 percent. Reduction to 7 percent statewide would only achieve an additional 2,000 af per year over the current BMPs at a cost of $300 per af.

In Chapters 7 through 9, these urban water conservation options are evaluated for each hydrologic region. The level of water conserved from these options will vary for each region depending on current urban water use and the hydrology of the region. Table 6-2 summarizes statewide urban water conservation options and the incremental depletion reductions for each option.

Table 6- 2. Statewide Urban Water Conservation Options Beyond BMPs

Hydrologic Region	Potential Depletion Reduction (taf) [1]							
	Reduction of Outdoor Water Use to 0.8 ET_0		Reduction of Residential Indoor Water Use to		Reduction of CII Water Use by		Reduction of Distribution System Losses to	
	Opt 1	Opt 2	Opt 3	Opt 4	Opt 5	Opt 6	Opt 7	Opt 8
	New	New & Existing	70 gpcd	65 gpcd	2%	3%	9%	7%
North Coast	2	10	D	D	2	3	D	D
San Francisco Bay	20	140	D	D	10	15	D	2
Central Coast	10	30	D	D	D	2	D	D
South Coast	140	500	D	D	20	25	D	D
Sacramento River	D	D	D	D	D	D	D	D
San Joaquin River	D	D	D	D	D	D	D	D
Tulare Lake	D	D	D	D	D	D	D	D
North Lahontan	D	D	D	D	D	D	D	D
South Lahontan	D	D	D	D	D	D	D	D
Colorado River	20	40	10	20	2	4	D	D
State Total	**192**	**720**	**10**	**20**	**34**	**49**	**--**	**2**

[1] In some regions, these levels of conservation are already being achieved. Urban water conservation beyond BMPs would not result in additional reductions in depletion in interior and Eastern Sierra regions and are deferred (D). Only depletion reductions greater than 1 taf are considered in this table.

Agricultural Water Conservation Options

The 1996 Memorandum of Understanding Regarding Efficient Water Management Practices by Agricultural Water Suppliers in California became effective when 15 agricultural water suppliers, representing 2 million acres of irrigated acreage had signed it. As of November 1997, the MOU had been signed by 29 water suppliers, serving about 2.8 million irrigated acres, as well as by other interested parties. The MOU establishes the Agricultural Water Management Council which will assume the responsibility of implementing the MOU, evaluating locally developed water management plans, and overseeing implementation of cost-effective efficient water management practices.

Baseline agricultural water use is calculated from estimates of crop acreage, unit applied water, unit evapotranspiration of applied water, and seasonal application efficiencies. Irrigated crop acreage was 9.5 million acres in 1995 and is expected to decline to 9.2 million acres by 2020 because of urbanization (mostly in the South Coast Region and San Joaquin Valley), westside San Joaquin Valley drainage problems, and changes in CVP water supply in the Central Valley.

Current EWMPs result in about 800 taf per year of applied water reductions by 2020, largely from canal lining or piping and other measures increasing average on-farm seasonal application efficiency to 73 percent. Recent DWR studies have shown that theoretical efficiencies might be increased to 80 percent through improved irrigation equipment and irrigation management practices. In some areas of the State, agencies such as Westlands Water District, Kern County Water Agency, and Imperial Irrigation District generally have on-farm efficiencies ranging from 75 percent to more than 80 percent.

The agricultural water conservation options described below were based on attaining seasonal application efficiencies greater than 73 percent, on average, through implementation of conservation measures in excess of present EWMPs. Average efficiencies of 76, 78 and 80 percent were used for the water management options. The Department's mobile laboratory data have shown these efficiencies can be achieved in certain locations and with some crops and irrigation methods.

Stressing orchards to reduce evapotranspiration (also referred to as regulated deficit irrigation) was not evaluated as an option. The RDI method was used successfully during the drought, but may impact crop yields and needs further testing as a long-term management strategy. RDI and other irrigation techniques to attain higher than 80 percent seasonal application efficiencies are discussed in Chapter 5.

The options below are evaluated for each hydrologic region. The water conserved from these options varies for each region according to prevailing irrigation practices and the regional soil types and hydrology. As with urban conservation options, the purpose of implementing these agricultural conservation options is to generate new water supply (by reducing depletions). Reducing consumptive use results in additional water supply only where water would otherwise be lost to evapotranspiration or to a saline water body such as the Pacific Ocean. In California agriculture, this condition exists primarily in the Colorado River Region (which drains to the Salton Sea), parts of the coastal area, and the westside of the San Joaquin Valley. In the Sacramento River and the San Joaquin River regions, almost all excess applied irrigation water is reused, ultimately percolating to groundwater or draining back into rivers that flow toward the Delta.

If all of the options discussed below were implemented, more than 200 taf of depletion reduction could theoretically be obtained. In areas where no depletion reductions would be achieved by conservation beyond EWMPs (such as the Sacramento and San Joaquin regions), this additional conservation was deferred as a water supply option. Most of the potential for achieving depletion reductions through additional agricultural conservation occurs in the Colorado River Region. However, the environmental impacts of such conservation on the Salton Sea would have to be carefully evaluated. The Salton Sea provides valuable habitat for migratory waterfowl, and alternatives for stabilizing its increasing salinity are now being studied. Since agricultural drainage provides the bulk of fresh water inflow to the sea, actions that would reduce the freshwater inflow may not be implementable on a large scale.

Irrigation Management. The Department assumes that by 2020, on-farm seasonal application efficiencies will average 73 percent statewide. Based on mobile laboratory studies, average seasonal application efficiencies could reach 80 percent through programs that include irrigation system evaluations, better system design, and improved irrigation systems and management practices. Options 1, 2, and 3 represent the depletion reductions that would be obtained with improved average SAE at 76, 78, and 80 percent, respectively.

Option 1: Improve Seasonal Application Efficiency to 76 percent. Average seasonal application efficiency in the Tulare Lake and Colorado River regions is close to 76 percent now. The depletion reduction for this option would be 10,000 af per year at about $100 per af.

Option 2: Improve Seasonal Application Efficiency to 78 percent. By improving SAE from 73 to 78 percent, depletion reductions would increase to 35,000 af per year for the Tulare Lake and Colorado River regions at a cost of $250 per af.

Option 3: Improve Seasonal Application Efficiency to 80 percent. Improving irrigation management from 73 to 80 percent seasonal application efficiency would result in depletion reductions of 60,000 af per year, mostly in the Colorado River Region at a cost of $450 per af.

Water Delivery Flexibility.

Option 4: Improve Water Delivery Flexibility. The manner of water delivery to the farm affects water use and use efficiency. Flexible water delivery allows a farmer to turn water on and off at will. This is impractical for many gravity flow agricultural water delivery systems because of the large volumes of water that must be delivered. However, some agricultural water agencies have been able to allow farmers to give shorter notice to the district before receiving water and to allow farmers to adjust flow rates and the duration of the irrigation. Flexible water delivery in the San Joaquin River Region could achieve 2,000 af in depletion reduction. Depletion reductions of 30,000 af could be attained in the Colorado River Region at a cost of about $1,000 per af.

Canal Lining and Piping

Option 5: Improve On-farm Distribution Systems. This option could improve water use efficiency by improving on-farm distribution systems beyond the level of effort provided in existing EWMPs. Distribution system losses can be reduced by lining open canal systems or using pipelines. Pipelines would reduce depletions from evaporation and from seepage of applied water to unusable groundwater. (This option applies only to canal lining and piping of on-farm delivery systems. Lining of major conveyance facilities such as the All American Canal, and lining of water agency-owned canals are treated as individual options in Chapters 7 through 9.)

Lining irrigation canal systems in the San Joaquin River region could reduce 2,000 af in depletions in areas that drain into unusable shallow groundwater. Less than 1,000 af in depletions would accrue in the Tulare Lake region because many irrigation systems on the westside of the valley where there is unusable shallow groundwater are already lined or piped. This option could save 45,000 af in the Colorado River region. It is estimated that this option would cost about $1,200 per af of depletion reduction.

Tail Water and Spill Recovery Systems

Option 6: Improve Tail Water and Spill Recovery. This option would improve irrigation efficiency by the construction of additional tail water and spill recovery systems. The tail water recovery option is only applicable to areas with furrow or border irrigation systems. Spill recovery systems would lessen the amount of water reaching unusable groundwater and surface water by reducing losses from operational spills in irrigation district delivery canals. About 65,000 af depletion reductions could be achieved in the Colorado River region with this option at a cost of about $150 per af.

Table 6-3 summarizes statewide agricultural water conservation options and the depletion reduction of each option. The agricultural options are deferred in a number of regions because the excess applied water either percolates to usable groundwater or flows to usable surface water. The only areas where the options significantly reduce depletions by preventing losses from entering unusable waters are the westside of the San Joaquin Valley and in areas tributary to the Salton Sea in the Colorado River Region. However, as mentioned earlier, the ability to conserve significant amounts of water beyond the base EWMPs in the Colorado River region will be limited by the need to preserve the environmental resources of the Salton Sea. These options are evaluated for the regional water management plans in Chapters 7, 8, and 9.

Table 6-3. Statewide Agricultural Water Conservation Options Beyond EWMPs

Hydrologic Region	Potential Depletion Reduction (Thousand Acre-Feet) [1]					
	Seasonal Application Efficiency Improvement			Flexible Water Delivery	Canal Lining and Piping [2]	Tailwater Recovery
	76%	78%	80%			
	Opt 1	Opt 2	Opt 3	Option 4	Option 5	Option 6
North Coast	D	D	D	D	D	D
San Francisco Bay	D	D	D	D	D	D
Central Coast	D	D	D	D	D	D
South Coast	D	D	D	D	D	D
Sacramento River	D	D	D	D	D	D
San Joaquin River	D	D	D	2	2	2
Tulare Lake	D	5	10	D	D	D
North Lahontan	D	D	D	D	D	D
South Lahontan	D	D	D	D	D	D
Colorado River [3]	10	30	50	30	45	65
State Total	**10**	**35**	**60**	**32**	**47**	**67**

[1] Implementation of some options in certain regions would not result in any depletion reduction and are deferred (D). Only depletion reductions greater than 1 taf are presented in this table.
[2] Excludes lining of major conveyance facilities (eg., All American Canal, Coachella Canal), which are treated as individual options in the regional water management chapters.
[3] These options are subject to environmental review to ensure that reduced depletions will not have significant impact to the Salton Sea.

Land Retirement

Land retirement is a demand reduction option that has been considered in the CALFED Bay-Delta planning process and in the CVPIA's least-cost yield increase study. Currently, two programs have authority to fund land retirement -- the CVPIA land retirement program and the San Joaquin Valley Drainage Relief Program created by State legislation in 1992. USBR's CVPIA Restoration Fund has the capability to provide significant amounts of funding for land retirement. By 2020 these programs, or other programs developed by local agencies, could implement land retirement for purposes such as improving water service reliability or improving drainage management. The use of the acquired water -- whether for agricultural, urban, or environmental purposes -- would depend on the authority and purpose of the program implementing the retirement.

For illustrative purposes, this Bulletin evaluates two land retirement options on the westside of the San Joaquin Valley, where some agricultural lands face serious drainage problems and where the existing land retirement programs are authorized to make acquisitions. The Interagency Drainage Program's 1991 report identified the need to retire 75,000 acres of lands with the worst drainage problems by 2040. Assuming that land retirement would occur uniformly over time, the Bulletin's 2020 irrigated acreage forecast includes a reduction of 45,000 acres of land as discussed in Chapter 4. The land retirement process, however, could be expanded and/or expedited through existing or future programs in which the land is purchased and then taken out of irrigated agriculture. Considering the region's chronic agricultural water shortages, it is likely that local water agencies would want to keep the water in the region to improve water supplies for remaining irrigated lands, as is being planned in a pending joint financing arrangement between USBR and Westlands WD.

For this Bulletin 160 update, two land retirement options were evaluated. Option 1 assumes that the full 75,000 acres of agricultural lands with the worst drainage problems recommended for retirement by 2040 by the interagency program would be retired by 2020, adding 30,000 acres to the base of 45,000 acres included in the Department's 2020 agricultural acreage forecast. The water savings from this additional 30,000 acres of retired lands would be about 65,000 af per year.

Option 2 assumes the retirement of up to 85,000 acres over the base 45,000 acres for a total of 130,000 retired acres. This includes the 30,000 acres in Option 1 plus other lands in the westside of the San Joaquin Valley with a selenium concentration of more than 200 parts per billion in shallow groundwater. Option 2 could result in 185,000 af/year of water savings. For option 2, the 200 ppb selenium criterion was used to benchmark acreage to be retired because of the 1991 interagency report's recommendations. Since publication of that report, there has been a decrease in the amount of land underlain by shallow groundwater, as observed by groundwater level monitoring in the drainage problem areas. This reduction can be attributed to several factors, including changes in growers' irrigation management and a reduction in surface water supplies to the westside of the valley. Since the interagency report's publication, there has been no new region-wide monitoring of selenium in shallow groundwater, and changes in the extent of lands underlain by high selenium groundwater are unknown. (Also since publication of the interagency report, the Department of Food and Agriculture has done further research which it believes indicates that lands within the 200 ppb selenium criterion delineation could perhaps still be used for irrigated agriculture. Land management practices would include planting halophytes and constructing solar evaporators to manage drainage. This form of land management is still at a research stage of development.)

To help put these acreage values into perspective, in 1997 USBR's land retirement program issued its first request for proposals from persons who wished to retire land pursuant to the CVPIA program. USBR received proposals totalling 27,500 acres. Based on its available budget, USBR expects to retire about 12,000 acres of the lands proposed.

Table 6-4 displays the crops assumed to be retired for both options along with the expected reductions in applied water and net depletions. Crop net depletions refers to the water consumed within a service area plus irrecoverable losses to salt sinks. Field crops are the primary types of crops assumed to be retired, with barley, wheat, cotton and safflower comprising almost 90 percent of total retired acreage for each option. The economic analysis includes the 45,000 acres of land contained in Bulletin 160-98's 2020 irrigated acreage forecasts to illustrate cumulative effects of land retirement, whether it is implemented by growers because of market forces or expedited through voluntary land purchase programs. This is a conservative assumption that does not reflect the economic impacts that would actually be attributable to option implementation.

Table 6-4. Land Retirement Options

Crops	*Option 1*				*Option 2*			
	Retired Acres		*Applied Water*	*Net Depletions*	*Retired Acres*		*Applied Water*	*Net Depletions*
	(Acres)	*(Percent)*	*(af)*	*(af)*	*(Acres)*	*(Percent)*	*(af)*	*(af)*
Alfalfa Hay	4,590	6.1%	18,360	16,570	7,010	5.4%	28,040	25,306
Irrigated Pasture	900	1.2%	3,780	3,285	1,000	0.8%	4,200	3,650
Barley	8,236	11.0%	11,530	10,377	14,320	11.0%	20,048	18,043
Wheat	12,354	16.5%	19,766	18,284	21,480	16.5%	34,368	31,790
Cotton	37,590	50.1%	105,252	98,110	66,360	51.0%	185,808	173,200
Safflower	7,650	10.2%	8,415	7,727	12,950	10.0%	14,245	13,080
Sugar Beets	340	0.5%	1,020	959	630	0.5%	1,890	1,777
Dry Beans	1,000	1.3%	4,000	3,610	2,000	1.5%	4,000	3,840
Dry Onions	370	0.5%	1,036	977	700	0.5%	1,960	1,848
Tomatoes (processing)	1,380	1.8%	3,864	3,671	2,630	2.0%	7,364	6,996
Almonds	333	0.4%	1,099	1,049	440	0.3%	1,452	1,386
Pistachios	37	0.0%	118	112	110	0.1%	352	333
Wine Grapes	220	0.3%	528	482	370	0.3%	888	810
Total	**75,000**	**100.0%**	**178,769**	**165,212**	**130,000**	**100.0%**	**304,615**	**282,059**

Cost of Land Retirement Program.

The costs of land retirement options are measured by the estimated costs to purchase farm land and remove it from irrigated agricultural production. Based upon land values for Fresno, Kings and Kern Counties estimated by the California Chapter of the American Society of Farm Managers and Rural Appraisers for the period of 1994 through 1996, the estimated cost of retiring the lands for Option 1 is about $1,550 per acre or $55 per acre-foot of net depletions. For Option 2, the estimated cost increases to about $1,760 per acre or $63 per acre-foot of net depletions. The increased cost is mainly due to the increased purchases of better quality, and thus more valuable, farmland as the voluntary farm land retirement program expands from Option 1 to Option 2.

The above costs assume that the farmland is permanently taken out of production. However, depending upon the location of the farmland, some may only be retired from irrigated agriculture, and not from agricultural production. Some of the land could still be grazed, or be used to grow dryland grains, safflower or grain hay. If it is assumed that all the retired land would still be used for grazing, then the estimated cost of retirement for Option 1 is about $1,420 per acre or $51 per acre-foot of net depletions. For Option 2, the estimated cost is about $1,640 per acre or $59 per acre-foot of net depletions assuming that all of the retired land could be used for grazing. Table 6-5 summarizes these costs.

Table 6-5. Costs of Land Retirement Options ($1995)

Land Retirement Assumptions	Option 1			Option 2		
	Total Cost Per Acre	Annualized Cost Per Acre [1]	Cost Per AF Net Depletions	Total Cost Per Acre	Annualized Cost Per Acre [1]	Cost Per AF Net Depletions
With No Alternative Uses	$1,550	$121	$55	$1,760	$138	$63
With Grazing	$1,420	$111	$51	$1,640	$128	$59

[1] For a 25 year period and 6% discount rate.

Direct farm income losses to farmers should be recovered through the land purchase costs discussed above. However, there is a potential for secondary economic impacts (third party effects) to the region (the regional economy is defined as Fresno, Kern and Kings Counties) and to the State. Indirect income and employment effects can occur to industries that supply farms with goods and services (for example, seed, fertilizer and farm labor) as well as to industries which transport and/or process agricultural produce for final consumption. Induced effects can also result from changes in household spending caused by changes in employment.

Tables 6-6 and 6-7 show the combined direct, indirect and induced value of production and employment effects for both the regional and statewide economies. As discussed above, some of these effects will likely be reduced because of potential alternative uses of the retired land (such as grazing or dry farming).

Table 6-6. Land Retirement Analysis--Option 1 Economic Impacts ($1995)

Crops	*Retired Land (Acres)*	*Direct, Indirect, Induced Effects*			
		Value of Production		*Employment*	
		Regional[1] ($1000)	*Statewide ($1000)*	*Regional[1] (person/yrs)*	*Statewide (person/yrs)*
Alfalfa Hay	4,590	7,711	8,109	109	113
Irrigated Pasture	900	670	705	9	10
Barley	8,236	4,622	5,250	77	79
Wheat	12,354	10,921	11,631	154	162
Cotton	37,590	95,148	101,519	1,567	1,587
Safflower	7,650	6,389	6,973	102	106
Sugar Beets	340	660	704	11	12
Dry Beans	1,000	1,680	1,767	24	25
Dry Onions	370	967	1,058	14	14
Tomatoes (processing)	1,380	4,579	5,010	64	65
Almonds	333	2,085	2,282	40	41
Pistachios	37	357	390	7	7
Wine Grapes	220	1,099	1,236	21	21
Totals	**75,000**	**136,888**	**146,633**	**2,200**	**2,240**

[1] Includes Fresno, Kern and Kings counties.

Table 6-7. Land Retirement Analysis--Option 2
Economic Impacts ($1995)

Crops	Retired Land (Acres)	Direct, Indirect, Induced Effects			
		Value of Production		Employment	
		Regional [1] ($1000)	Statewide ($1000)	Regional [1] (person/yrs)	Statewide (person/yrs)
Alfalfa Hay	7,010	11,777	12,384	166	173
Irrigated Pasture	1,000	745	783	11	11
Barley	14,320	8,036	9,128	135	138
Wheat	21,480	18,988	20,223	268	281
Cotton	66,360	167,970	179,218	2,767	2,801
Safflower	12,950	10,815	11,804	173	179
Sugar Beets	630	1,222	1,304	20	22
Dry Beans	2,000	2,616	2,972	44	45
Dry Onions	700	1,829	2,001	26	26
Tomatoes (processing)	2,630	8,727	9,549	122	124
Almonds	440	2,755	3,015	53	54
Pistachios	110	1,061	1,161	20	21
Wine Grapes	370	1,849	2,079	36	36
Totals	**130,000**	**238,391**	**255,620**	**3,840**	**3,909**

[1] Includes Fresno, Kern and Kings Counties.

Environmental Water Conservation Options

To date, there has been little formal planning for environmental water conservation, unlike the urban and agricultural efforts discussed above. Development of a formal program to evaluate efficient water use on wetlands is currently the only program being considered. The DFG, USBR, and USFWS are working with the Grasslands Resource Conservation District to develop an interagency program for water use planning for Central Valley wildlife refuges covered by the CVPIA. This program will include best management practices for efficient water use, and will develop a planning process for refuges. Draft work products were expected to be developed by October 1997. At this point, no options for wetlands water conservation have been quantified.

Water Supply Augmentation Options

At the present time, most active planning for statewide water supply options is being done either for the CALFED Bay-Delta program or for SWP future supply. In accordance with the requirements of the CVPIA, an appraisal level water supply augmentation report was recently prepared for the CVP, but there has not been action to implement potential CVP supply options described in that report.

Improving Delta Conditions

The San Francisco Bay/Sacramento-San Joaquin Delta estuary is the center from which two-thirds of the State's population and millions of acres of agricultural land receive part or all of their water supplies. Implementation of many statewide water supply augmentation options would include improving Delta conditions. Voter approval of Proposition 204 in the 1996 general election demonstrates public support for developing a long-term Bay-Delta solution and restoring the Delta environment. Below is a review of programs to improve Delta water supply reliability.

Interim South Delta Program.

The Department's Interim South Delta Program plans to improve water levels and circulation in south Delta channels for local agricultural diversions, and to enhance existing delivery capability of the SWP by improving south Delta hydraulic conditions, allowing increased diversions into Clifton Court Forebay. This would allow for full pumping capacity at the SWP's Banks Pumping Plant (10,300 cfs) during high flows in the Delta and more operational flexibility for the SWP to reduce fishery impacts.

The ISDP is partially in response to the proposed settlement of a lawsuit brought by the South Delta Water Agency against the Department and USBR. In the proposed settlement agreement, the three parties committed to develop mutually acceptable long-term solutions to the water supply problems of local water users within SDWA. The Department has taken the lead responsibility for planning and constructing the project, with cost-sharing provided by USBR.

The ISDP preferred alternative would cost an estimated $60 million to construct and includes the following five project components:

(1) Construction and operation of a new intake structure at northeastern corner of Clifton Court Forebay, as part of providing greater operational flexibility in export pumping.

(2) Channel dredging along 4.9 miles of Old River just north of Clifton Court Forebay.

(3) Construction and seasonal operation of a barrier at the head of Old River in spring and fall to improve fishery conditions for salmon migrating in the San Joaquin River.

(Construction of an Old River fishery barrier is included in the CVPIA's list of mandated federal environmental restoration actions.)

(4) Construction and operation of three flow control structures at Old River, Middle River, and Grant Line Canal, to improve existing water level and circulation patterns for agricultural users in the south Delta.

(5) Increased diversions into Clifton Court Forebay up to a maximum of 20,430 af daily on a monthly averaged basis, resulting in the ability to pump an average of 10,300 cfs at Banks Pumping Plant.

The ISDP could augment SWP supplies by 125 taf/year in average years and 100 taf/year in drought years at a 2020 level of demand. The Draft EIR/EIS for the program was released in July 1996, with public hearings held in early 1997. The Final EIR/EIS is scheduled for completion in mid-1998.

CALFED Bay-Delta Program.

The CALFED Bay-Delta Program was established in May 1995 to develop a long-term plan for restoring ecological health, improving water quality, improving levee system integrity, and improving water management for beneficial use of the Bay-Delta system. It is a cooperative effort among state and federal agencies and the public. State and federal agencies participating in the CALFED program are shown in Table 6-8.

Table 6-8. CALFED Agencies

California	*Federal*
The Resources Agency	Environmental Protection Agency
Department of Water Resources	Department of Interior
Department of Fish and Game	Bureau of Reclamation
California Environmental Protection Agency	Fish and Wildlife Service
	U.S. Army Corps of Engineers
	Department of Agriculture
	Natural Resources Conservation Service
	Department of Commerce
	National Marine Fisheries Service

The CALFED Bay-Delta Program is carrying out a three-phase process to achieve broad agreement on comprehensive solutions for the Bay-Delta system. During Phase I, completed in August 1996, the program defined fundamental problems in the Bay-Delta system. This resulted in an initial set of alternatives, or sets of actions to be evaluated in Phase II. Phase II is currently underway and will be completed in September 1998. It includes a programmatic environmental review, refinement of the three alternative solutions, and selection of a preferred alternative. During Phase III, which will begin in late 1998 or early 1999 and continue for 20 to 30 years, the preferred alternative will be implemented.

The three conceptual alternatives developed in Phase I to solve Bay-Delta problems all include program components to comprehensively address ecosystem restoration, water quality improvements, enhanced Delta levee system integrity, and increased water use efficiency. The key variable distinguishing the alternatives from one another is how each would move and store water within the Bay-Delta system:

- **Alternative 1:** Water is conveyed through the Delta using the current system of channels.
- **Alternative 2:** Water conveyance through the Delta is substantially improved by making significant changes to the existing system of channels.
- **Alternative 3:** Water conveyance through the Delta is substantially improved by making significant changes to the existing system of channels and constructing a conveyance facility, isolated from the Delta's natural channels, to transport part or all of the water intended for export.

Each alternative presents options for water storage, as well as a system for conveying water through and/or around the Delta. The water storage element could include expanding existing storage, constructing new surface storage, or conjunctive use and groundwater banking. Additional storage would increase flexibility in operating the Bay-Delta system, allowing operators to respond to changing conditions and needs throughout the year, and would help respond to the effects of drought. Surface storage could be in the Delta, upstream of the Delta, or south of the Delta. Groundwater storage components include conjunctive use and groundwater banking programs in the Sacramento and San Joaquin Valleys and in the Mojave Basin.

Preliminary evaluations of potential offstream reservoir sites upstream of the Delta indicate that four reservoir sites are likely finalists of the CALFED screening process for North of the Delta. These proposed reservoir sites are: Red Bank Project (Dippingvat and Schoenfield reservoirs), Thomes-Newville Reservoir, Sites Reservoir, and Colusa Reservoir. DWR, authorized by Proposition 204, has begun an investigation to evaluate these four sites. (Descriptions of these, and other, statewide options for new surface storage are provided in the following section.)

Since these projects are offstream storage projects, their major components would be water diversion and conveyance facilities. Alternative water supply concepts are being investigated. Surplus flood flows from local tributaries, the Colusa Basin Drain, and the Sacramento River are being looked at as potential sources of water supply. Expansion of existing water conveyance facilities, such as the Tehama-Colusa Canal and the Glenn-Colusa Canal, and a new diversion from the Sacramento River downstream of Chico Landing are being evaluated.

CALFED Bay-Delta Program Common Programs

During Phase I it was determined that all alternatives to solve Bay-Delta system problems needed to include four common programs. These common programs are:

Ecosystem Quality — restore the ecosystem to levels needed to support Bay-Delta species at naturally sustainable levels, including the habitats necessary for survival of species that use the ecosystem. Potential measures are discussed in the Environmental Enhancement Options section.

Levee System Integrity — reduce the risk of levee failure due to floods, earthquakes and general deterioration by developing a long-term maintenance plan and an emergency levee management plan.

Water Quality — focus on controlling pollution at its source. Reducing the amount of pollutants entering the Delta benefits all water users by reducing salt loading for agricultural diversions, improving drinking water quality, and improving water quality for the ecosystem.

Water Use Efficiency — implement programs that increase the efficiency with which water is used, including conservation and water recycling.

Statewide Option for Conveyance Facilities

The Mid-Valley Canal has been proposed as a major conveyance facility to supplement water supplies to the eastern San Joaquin Valley. The Mid-Valley Canal, with two components -- a main branch and a north branch -- would convey existing CVP water supply from the

Sacramento-San Joaquin Delta to portions of Merced, Madera, Fresno, Kings, and Tulare counties and, by exchange, Kern County.

The main branch of the Mid-Valley Canal would convey water from the Mendota Pool down the east side of the valley, providing additional water deliveries to the southern San Joaquin Valley and Tulare Lake Basin. The north branch would divert water out of the Mendota Pool to provide additional water deliveries to the eastern San Joaquin Valley. Water deliveries could be used for conjunctive use and groundwater banking programs, alleviating groundwater overdraft conditions. Improved groundwater conditions, through delivery of surplus Delta flows could increase the reliability of dry year supplies.

Because of the uncertainty of Delta exports, this option is deferred from further analysis in this Bulletin as a statewide option. However, the Mid-Valley Canal is a potential conveyance facility that could be considered in the formulation of storage and conveyance alternatives in the CALFED process.

Statewide Options for Surface Storage Facilities

One option to improve statewide water supply reliability is to develop additional surface storage. New storage facilities could store water for the environment, agriculture, municipalities, industry, or a combination of these uses. More storage would increase flexibility in operating the Bay-Delta system, improving operators' ability to respond to changing conditions and needs throughout the year. Potential statewide storage options are in-Delta storage, reservoir sites upstream of the Delta supplied by the Sacramento or San Joaquin rivers or their tributaries, and off-aqueduct storage south of the Delta, supplied with water exported from the Delta. These storage options are being evaluated as part of CALFED's review of Phase II alternatives.

In the CALFED process, no allocation has yet been made of the water supply that could be provided from new surface storage facilities, nor of the costs for constructing the facilities. For illustrative purposes, the following sections on new storage facilities treat some of the facilities as if they were part of the SWP, to provide a benchmark for calculating their yields via operations studies. Many of these sites have been studied historically as potential SWP future water supply facilities, and data available for them reflect that intended purpose. The Bulletin's treatment of these facilities as potential components of the SWP is to facilitate their quantification, and is not intended to be a proposal as to the agency that would actually finance, construct, and own them.

Multipurpose Facilities

Most reservoirs are constructed to serve multiple purposes. As discussed in Chapter 3, multipurpose reservoirs are often operated to prioritize certain uses, or to balance competing uses during different times of the year. Good planning policy dictates that new surface storage facilities be designed to accommodate as many purposes -- such as water supply, flood control, hydropower generation, fish and wildlife enhancement, water quality management, and recreation -- as are practicable.

The discussion that follows is focused on potential water supply augmentation opportunities from new reservoirs in the Central Valley, reflecting Bulletin 160's goal of evaluating water supplies and water demands and the CALFED Bay-Delta Program's goal of evaluating water supply options. This focus is not intended to minimize the need to consider the other benefits potentially available from these reservoir sites -- especially flood control. The January 1997 flooding, the largest and most extensive flood disaster in the State's history, demonstrated the urgent need to improve flood protection levels throughout the Central Valley. The 1997 *Final Report of the Governor's Flood Emergency Action Team* contained a variety of recommendations for improving emergency response management and flood protection in the Central Valley.

☞Photo: levee break

The 1997 floods highlighted a fundamental fact of Central Valley geography -- the valley floor is relatively flat, and only an extensive system of levees confines floodwaters to those areas where people would prefer that they remain. At the beginning of the Valley's development in the Gold Rush era, much of the valley floor was an inland sea during the winter months, and travel was possible only by boat. This condition was once again experienced on a localized scale in 1997, when numerous levee breaks occurred throughout the valley. Although more emphasis is being given to floodplain management and prevention of future development in flood-prone areas, extensive urban development has already occurred in areas that rely on levees for flood protection. Efforts to improve flood protection for these urban areas necessarily include evaluation of upstream storage alternatives -- reoperation or enlargement of existing reservoirs and construction of new reservoirs.

The discussion that follows on statewide water supply augmentation options covers some opportunities for improvement of flood protection, focusing on those areas where increased flood storage is most needed. Local options for water supply/flood protection reservoirs are described in Chapters 7 through 9.

Upstream of the Delta

Review of potential statewide storage options upstream of the Delta revealed that most of the water development potential of the eastern Delta and San Joaquin River tributaries is likely to be dedicated to local plans. The Sacramento River Basin presents nearly all the potential for additional development to meet statewide needs.

The Sacramento River Basin produces nearly one-third of California's surface runoff. Numerous water storage reservoirs throughout the basin regulate much of that runoff to support extensive agricultural development within the region, and also provide significant water supply for export to other regions from CVP and SWP facilities. A potential remains for developing additional storage in the basin, as evidenced by frequent storm-season outflows in excess of in-basin and Delta needs.

Over the past century, planners have examined hundreds of potential reservoir storage sites encompassing every significant tributary of the Sacramento River Basin. The most economical and practicable of those were developed (largest of which are Lakes Shasta, Oroville, Berryessa, Almanor, Folsom, and New Bullards Bar). As planners consider possibilities for additional storage, they are primarily reexamining past project proposals.

The average annual surplus outflow in the Sacramento River Basin is about 9 maf. While this suggests potential for additional storage development, much of the surplus runoff occurs during short periods in years of exceptional flood runoff. For example, a maximum daily flow of about 600,000 cfs flowed past the latitude of Sacramento during the floods of February 1986 and January 1997. It is only practical, and environmentally acceptable, to create new storage capacity to capture a small fraction of such flood outflows.

Total reservoir storage in the basin is around 16 maf. In the long term, the water available to refill that storage is the average annual surplus outflow. A significant average surplus outflow is needed to maintain the hydrologic reliability of the system (its ability to recover from severe storage drawdown during drought periods). Attempting to store too large a share of the remaining surplus flow would jeopardize dry-period capability while overemphasizing long-term average supply capability, because perfectly efficient reservoir operation could only occur if water managers had precise knowledge about future weather conditions.

Prospects for the development of additional onstream surface storage reservoirs are:

- **Upstream from Shasta Dam**. About 26 percent of basin runoff originates in this 6,700-square mile tributary area, primarily in the Pit, McCloud, and upper Sacramento rivers. The availability of water to support additional storage has long been recognized. In the 1930s, Shasta Dam planners considered a larger project, but opted for construction of storage downstream at the Table Mountain or Iron Canyon sites near Red Bluff. When the downstream dam proved environmentally unacceptable, alternatives examined eventually included enlarging Shasta Dam, which is costly and has high environmental impacts. New storage upstream is possible, but sites are limited by steep topography and extensive existing power development of the Pit and McCloud systems.
- **Upper Sacramento River Tributaries, Shasta Dam to Red Bluff.** This large, but low-elevation, area contributes about one-eighth of Sacramento River Basin runoff. The principal tributaries (in descending order of runoff) are Cottonwood, Cow, Clear, and Battle creeks. Clear Creek is fully developed by Whiskeytown Lake (a CVP facility). Several reservoir sites have been investigated on the other tributaries, with primary emphasis on Cottonwood Creek. Previously studied reservoir sites are available in this area, but none have proven viable.
- **Feather River.** This is the Sacramento River's largest tributary and contributes 20 percent of basin runoff, an annual average of about 4.5 maf. Lake Oroville at 3.5 maf regulates Feather River flows in most years, but the huge spills in wet years show that the river could support additional storage. Enlargement of Lake Oroville has not been considered practical and the few upstream sites identified in the past have fallen by the wayside for various environmental and economic reasons. No serious planning attention

has been devoted to major reservoir storage in the Feather River Basin since construction of Oroville Dam.

- **Yuba and Bear Rivers.** The natural flow of the Yuba constitutes 11 percent of Sacramento River Basin runoff, but is substantially diminished by power diversions to the adjacent Bear and Feather rivers. Still, a significant potential for additional storage remains. Proposals for reservoirs at the Marysville (or nearby Narrows) site have been discussed in the past 40 years; none has appeared particularly attractive from an economic perspective and all have proven controversial. Upstream development potential is restrained by extensive existing power facilities and diversions. The Bear River is small, but its runoff is bolstered by the diversions from the Yuba. Local interests are considering additional storage to supplement the existing Camp Far West Reservoir.
- **American River**. With 12 percent of Sacramento Basin runoff, the American River could support more than the 1.0 maf of storage provided by Folsom Lake and the nearly 0.5 maf of upper basin storage. For the past decade, recognition of a flooding hazard along the lower American River has added urgency to finding options, including enlarging Folsom Lake, and construction of additional storage upstream at Auburn. The controversy over Auburn Dam prompted reappraisal of storage sites farther upstream and on the South Fork, but none appeared to justify follow-up attention.
- **Westside Tributaries South of Cottonwood Creek**. The principal tributaries in this group are (from south to north): Putah, Cache, Stony, Thomes, Elder, and Red Bank creeks. The existing Lake Berryessa, which has an unusually high storage/inflow ratio, fully develops Putah Creek. Clear Lake and Indian Valley Reservoir provide about 0.6 maf of active storage in the upper Cache Creek Basin, but only modest potential exists for additional storage in the lower basin. East Park, Stony Gorge, and Black Butte reservoirs partially control Stony Creek, but some surplus water remains. Thomes, Elder, and Red Bank creeks are presently uncontrolled; Thomes Creek contributes about two-thirds of the runoff from this northern trio. Potential reservoir sites have been considered on the various westside tributaries, principally within the Stony/Thomes basins.
- **Eastside Tributaries, Feather River to Red Bluff**. From south to north, the major streams of this group are Butte, Big Chico, Deer, Mill, and Antelope creeks. These

drainages are narrow, steep canyons with good sustained summer flows. Past studies have identified a few small potential storage sites, but none are considered practical because of environmental considerations (primarily anadromous fish and wilderness issues).

These seven areas contribute more than 80 percent of Sacramento River Basin runoff. The remaining runoff originates within the substantial valley floor area and adjacent low-elevation foothills. With few exceptions, streams draining this area are ephemeral, flowing only during and following storms. No consideration has been given to onstream storage on these minor tributaries or nearby valley floor areas, except for discussion of possible winter storage in rice fields.

Besides the onstream reservoir sites proposed over the years, many potential offstream storage developments on Central Valley tributaries have been investigated. Major planning on such projects began in the 1970s, in the wake of wild and scenic rivers legislation that effectively eliminated additional development of the North Coast Rivers. By then, it was also apparent that additional storage on the Sacramento River downstream from Lake Shasta was not environmentally feasible, so planners shifted attention to various onstream tributary reservoirs and to offstream sites that could develop some of the surplus water of the upper basin. With one exception (Tuscan Buttes Reservoir on Inks Creek, north of Red Bluff), the most promising offstream storage sites investigated during this time lay west of the river from the Stony Creek Basin (Newville and Glenn Reservoirs) south (from Colusa and Sites Reservoirs) to the Putah Creek Basin (enlarged Lake Berryessa). All these projects would require massive conveyance facilities to divert surplus flow (usually during flood periods) from the Sacramento River with pump lifts of 300 to 900 feet. Offstream storage projects of this type can be sited to minimize environmental detriments within the inundation area, but diversions from the river involve engineering and environmental challenges.

There has been a revival of interest in other offstream storage possibilities, some new and some that appeared in the Department's Bulletin 3, *The California Water Plan*, in 1957. Among the latter is a potential local project, Waldo Reservoir, to store surplus Yuba River water diverted from the existing Englebright Reservoir. Similar proposals have been developed to store surplus American River water from Folsom Reservoir in the nearby Deer Creek or Laguna Creek basins. Offstream storage projects of this type are attractive because they eliminate the need for controversial onstream reservoirs such as Marysville and Auburn, and divert from existing facilities upstream from current anadromous fishery habitat.

From a flood control standpoint, there are locations within the Sacramento and San Joaquin river systems where additional storage (onstream, or perhaps offstream with appropriate diversion and pumping capability) would be particularly useful. Communities in the Sacramento Valley with greatest need for additional flood protection include the Yuba City/Marysville area, and Sacramento/West Sacramento area, as identified in the 1997 *Final Report of the Governor's Flood Emergency Action Team.* An enlarged Shasta Lake could provide management of flood flows on the Sacramento mainstem. The need for additional flood control storage on the Yuba River has been evaluated for some time, in conjunction with reservoir sites such as the old Marysville site, or the more recent Parks Bar alternative. The proposed Auburn Dam on the American River (described earlier), selected as the preferred flood protection alternative by the State Reclamation Board, would provide much-needed flood protection for the Sacramento area, which has one of the lowest levels of flood protection of any metropolitan area in the nation.

In the San Joaquin Valley, urbanized areas needing additional protection are those affected by flooding on the mainstem San Joaquin River and on its largest tributary, the Tuolumne. In the January 1997 flood event, runoff at New Don Pedro Dam on the Tuolumne and Friant Dam on the San Joaquin exceeded the flood control capability of both reservoirs. On the Tuolumne it appears that new upstream reservoirs are a less likely flood control option, given the basin's existing storage development. Enlarging Friant Dam (or constructing its offstream alternative) would be the most probable new storage development option for the San Joaquin River.

Evaluation of Onstream Storage Options. The initial screening of storage options for statewide water supply included the 33 reservoir sites shown in Table 6-9. These sites have been investigated, so information was available to support a preliminary assessment. After the initial screening, 15 remaining options were examined in detail. This appraisal relied on previous studies covering traditional project formulation, engineering feasibility, cost, and environmental aspects. The older studies were supplemented by a cursory reexamination of environmental aspects that reflected the most recent information on critical habitat, wetlands, endangered species, and cultural resources. Because past studies were limited, these environmental reexaminations generated few conclusive findings. The larger reservoirs on major waterways tend to have the most potential environmental consequences. And, there is a definite correlation between the intensity of prior studies and the number of known potential environmental problem issues. The potential environmental issues at the 15 retained options are shown in Table 6-10.

Table 6-9. Comprehensive List of Onstream Surface Options Upstream of the Delta.

Stream (clockwise around basin)	Reservoir	Retain or Defer	Reason for Deferral
Cache Creek	Wilson Valley	Defer	Defer in favor of alternate site in same general area.
	Kennedy Flats	Defer	Defer in favor of alternate site in same general area.
	Blue Ridge	Retain	
Stony Creek	Newville	Retain	Part of Thomes-Newville
Thomes Creek	Thomes Division	Retain	Part of Thomes-Newville
	Paskenta	Defer	Defer in favor of alternate site in same general area.
Elder Creek	Gallatin	Defer	Limited water supply to support significant amount of storage
Red Bank Creek	Schoenfield	Retain	Part of Red Bank Project
S.F. Cottonwood Creek	Dippingvat	Retain	Part of Red Bank Project
	Rosewood (Dry Creek)	Defer	Limited water supply to support significant amount of storage.
	Tehama	Retain	
M.F. Cottonwood Creek	Fiddlers	Retain	
Cottonwood Creek	Dutch Gulch	Retain	
N.F. Cottonwood Creek	Hulen	Retain	
Lake Shasta Tributaries	Shasta Enlargement	Retain	
	Squaw Valley (Squaw Valley Cr.)	Defer	Defer due to high costs and substantial environmental impacts.
	Kosk (Pit River)	Retain	
	Allen Camp (Pit River)	Defer	Primarily a local project, not well suited for statewide supply augmentation
Little Cow Creek	Bella Vista	Defer	Defer due to high costs and substantial environmental impacts.
South Cow Creek	Millville	Retain	
Inks Creek	Wing	Retain	

Table 6-9. Comprehensive List of Onstream Surface Options Upstream of the Delta.

Stream (clockwise around basin)	Reservoir	Retain or Defer	Reason for Deferral
Deer Creek	Deer Creek Meadows	Defer	Primarily a local project, not well suited for statewide supply augmentation. Also doubtful environmental feasibility.
Upper Feather River	Abbey Bridge (Red Clover Creek)	Defer	Primarily a local project, not well suited for statewide supply augmentation. Also doubtful environmental feasibility.
	Dixie Refuge (Last Chance Creek)	Defer	Primarily a local project, not well suited for statewide supply augmentation. Also doubtful environmental feasibility.
Yuba River	Marysville/Narrows	Defer	Defer due to high costs and substantial environmental impacts.
M.F. Yuba River	Freemans Crossing	Defer	Limited water supply to support significant amount of storage and doubtful environmental feasibility.
Bear River	Garden Bar	Defer	Primarily a local project.
N.F. American River	Auburn	Retain	
American River	Folsom Enlargement	Retain	
S.F. American River	Coloma/Salmon Falls	Defer	Defer due to environmental and social/third party impacts.
Cosumnes River	Nashville	Retain	
Mokelumne River	Pardee Enlargement	Defer	Being actively pursued by local interests; not available for statewide supply.
San Joaquin River	Millerton Enlargement	Retain	

Table 6-10. Summary of Retained Onstream Reservoirs and Environmental Issues

	Storage Volume (maf)	$/af of Active Storage	Potential Environmental Issues
Very Large Reservoirs			
Enlarge Lake Shasta	up to 10		stream/river habitat; wild & scenic rivers; trout fisheries; downstream salmon; downstream seepage and erosion impact; deer; numerous listed and candidate species; cultural resources; disruption of established development
Auburn	0.85 - 2.3		stream habitat; wetlands; wildlife; trout; listed amphibian, insect, and plant species; cultural resources; recreation impacts
Thomes-Newville	1.4 - 1.9		deer winter range; stream habitat; cultural resources; possible minor salmon/steelhead runs
Large Reservoirs			
Tehama	0.5 - 0.7		riparian habitat; salmon/steelhead; deer; upland game; bald eagles; cultural resources; various listed species possible
Dutch Gulch	0.7 - 0.9		riparian habitat; salmon/steelhead; deer; upland game; bald eagles; cultural resources; various listed species possible
Kosk	0.8		stream habitat; deer; elk; bear; upland game; eagles; spotted owls; trout; Big Bend Indian Rancheria
Blue Ridge	0.95		stream habitat; rafting uses; Tule elk
Nashville	0.9		wetland/marsh habitat; stream habitat; deer; upland game
Enlarge Millerton Lake	0.5 - 0.9		stream and upland habitat; disruption of established development
Small to Medium Reservoirs			
Wings	0.25 - 0.5		salmon/steelhead (Battle Creek); deer; several listed bird, amphibian, insect, plant species
Red Bank Project	0.35		stream habitat; California red-legged frog; spring-run salmon
Millville	0.1 - 0.25		stream habitat; salmon
Hulen	0.2 - 0.3		Fossils; stream habitat
Enlarge Folsom Lake	0.37		stream and upland habitat; eagles; several listed plant species; cultural resources; disruption of established development
Fiddlers	0.2 - 0.5		stream habitat

The appraisal process confirmed that larger projects tend to have the potential to produce less costly and more reliable water supply, but have greater potential impacts on the environment. There is no one accepted method to compare options, particularly those of vastly differing size, but clear conclusions emerged from assessing options within similar groups.

Very Large Onstream Reservoirs (Over 1.0 maf). With the potential to provide up to 10 maf of additional storage, Enlarged Lake Shasta is in a class apart; at large sizes, it could provide new storage at a favorable unit cost, but with substantial financial and environmental consequences. In the 1.0 - 2.5 maf range, Auburn Reservoir ranks high, but is burdened with well- publicized environmental controversies. As discussed in Chapter 3, there is an urgent need for greater flood protection on the American River, and a dam at Auburn has been identified by the State as the best flood control alternative. A Thomes-Newville development in the Stony Creek basin remains a possibility, provided it is sized to match its limited water supply; the site also has potential for offstream storage of adjacent basin or Sacramento River water.

Large Onstream Reservoirs (0.5 to 1.0 maf). Tehama and Dutch Gulch reservoirs in the Cottonwood Creek Basin clearly warrant further consideration, possibly at smaller sizes than the 0.7 and 0.9 maf considered in the 1983 U.S. Army Corps of Engineers feasibility study. As an alternative to Dutch Gulch, the upstream Fiddlers Reservoir site has promise (but its optimum size may be smaller than 0.5 maf).

Raising Friant Dam on the San Joaquin River by 120 to 140 feet could more than double the current 520 taf capacity of Millerton Lake; while the expansion would be expensive, it is the only San Joaquin Valley surface storage option that appears to offer potential for statewide supply augmentation. Enlarging Friant Dam also would provide flood control benefits.

Kosk Reservoir on the Pit River, Blue Ridge Reservoir on Cache Creek, and Nashville Reservoir on the Cosumnes River appear to offer some promise for storage in this size range, but scant current information is available on their cost, water supply efficacy, or environmental impacts. Reconnaissance reappraisals could fully assess the practicability of these three sites.

Coloma Reservoir on the South Fork American River could provide storage within this size range, but any size over 0.2 maf would inundate the town of Coloma and the Marshall Gold Discovery State Historic Park (which would require legislative authorization under Water Code Section 10001.5); Coloma and the nearby Salmon Falls alternative are unpromising and are deferred from further consideration. Marysville and Narrows reservoirs on the Yuba River also are deferred from further consideration because local interests are evaluating a small facility as a local project.

Small-to-Medium-Sized Onstream Reservoirs (0.1 to 0.5 maf). Seven options within this range were among those selected for analysis. Three of those on upper Sacramento Valley tributaries appear to offer acceptable combinations of water supply capability, cost, and environmental compatibility. The largest of these, Wing Reservoir on Inks Creek with a diversion from Battle Creek, could provide over 0.4 maf of storage. The other apparently viable options, both near the lower limit of this size range, are the Red Bank Project on South Fork Cottonwood and Red Bank creeks, and Millville Reservoir on South Cow Creek. One of the two on-stream reservoirs developed by the Red Bank Project would be used primarily as an off-stream storage facility. Hulen Reservoir, on North Fork Cottonwood Creek, would be high on the list except it would inundate a premier deposit of Cretaceous fossils. (Medium-sized projects involving Cottonwood Creek water are alternatives, not adjuncts, to the larger downstream Tehama and Dutch Gulch storage sites.)

Enlargement of Folsom Lake is among the options being considered to provide additional flood control along the lower American River. If that enlargement proves practicable, it could provide a valuable increment of water supply storage (depending on the flood operating criteria). That storage would be expensive, so it is unlikely except as an element of a comprehensive flood control package.

The remaining two medium-sized options are Bella Vista Reservoir on Little Cow Creek near Redding and Squaw Valley Reservoir on Squaw Valley Creek near McCloud. These projects appear more expensive and more environmentally disruptive than the competing options. Therefore, they are not considered promising prospects for future development and are deferred from further evaluation.

Evaluation of Offstream Storage Options. The initial screening of upstream-of-the-Delta offstream storage options included the 15 proposals in Table 6-11. The initial screening indicated that nine of those warranted further examination, including a review of past studies and a cursory reexamination of the latest available environmental information. The potential environmental issues identified with the retained options are shown in Table 6-12.

Offstream storage has an inherent environmental advantage because the reservoirs tend to be on minor tributaries, which reduces impacts on live streams and riparian habitat. For most of the larger offstream options, that advantage must be balanced against the potentially severe environmental impacts with diversions from major nearby streams. Evaluating the nine retained options from that perspective leads to the following general conclusions.

Table 6-11. Comprehensive List of Offstream Surface Storage Options Upstream of the Delta

Stream Basin (clockwise around basin)	Offstream Reservoir	Retain or Defer	Reason for Deferral
Putah Creek	Berryessa Enlargement	Retain	
Various	Sites	Retain	
Various	Colusa	Retain	
Stony Creek	Thomes-Newville	Retain	
Stony Creek	Glenn	Retain	
S.F. Cottonwood Creek	Red Bank Project	Retain	
Trinity River	Clair Engle Enlargement	Retain	
Inks Creek	Tuscan Buttes	Defer	Defer due to substantial environmental impacts.
Bear River	Waldo	Defer	Being actively pursued by Yuba County Water Agency; not considered for statewide supply.
Deer Creek	County Line	Defer	Defer in favor of alternate site in same general area.
Deer Creek	Deer Creek	Retain	
Laguna Creek	Clay Station	Retain	
Calaveras River	Duck Creek	Defer	Defer due to extraordinarily high costs.
Calaveras River	South Gulch	Defer	Primarily a local project, not well suited for statwide supply augmentation.
Littlejohns Creek	Farmington Enlargement	Defer	Primarily a local project, not well suited for statwide supply augmentation.

Table 6-12. Summary of Retained Offstream Options and Environmental Issues

	Storage Volume (maf)	Potential Environmental Issues
Very Large Reservoirs		
Berryessa Enlargement	up to 11.5 additional	stream habitat; wetlands; deer and upland game; Putah Creek trout fishery; Sacramento River anadromous fish; listed/sensitive plant species; cultural resources; disruption of established agriculture and recreation; population displacement
Thomes-Newville	1.4 -1.9	deer winter range; stream habitat; cultural resources; possible minor salmon/steelhead runs
Glenn	6.7 - 8.7	stream habitat; wetlands/vernal pools; deer and upland game; deer winter range; Sacramento River anadromous fish; eagles; cultural resources; population displacement
Clair Engle Enlargement	4.8 additional	stream habitat; wetlands/marshes; sensitive plants; eagles; spotted owls; anadromous fish (Trinity and Sacramento rivers)
Sites	1.2 - 1.8	Sacramento River anadromous fish
Colusa	3.0	Sacramento River anadromous fish
Large Reservoirs		
Deer Creek	0.6	vernal pools; meadow/marsh habitat; listed bird, invertebrate, insect, and plant species, cultural resources
Small to Medium Reservoirs		
Red Bank	0.35	stream habitat; California red-legged frog; spring-run salmon
Clay Station	0.2	stream habitat; wetlands; meadow/marsh habitat; listed bird, invertebrate, insect, and plant species

Very Large Offstream Reservoirs (Over 1.0 maf). Three of the six very large reservoir options have the potential to provide more than 4 maf of new storage, but not without some considerable environmental effects. The existing 1.6-maf Lake Berryessa could be enlarged to provide massive amounts of storage for surplus flows pumped from the lower reaches of the Sacramento River. Past studies have shown the unit cost of storage in the large project sizes would be attractive, though a 31-mile conveyance facility with a 700-foot pump lift would be required. The financial and energy costs of this conveyance would be enormous, as would the environmental consequences. Diversion of around 12,000 cfs from the lower river could prove challenging. Under current conditions, offstream storage of Sacramento River water in enlarged Lake Berryessa does not appear to hold much promise in the foreseeable future.

Similarly, a Glenn Reservoir, a combination of Thomes-Newville Reservoir on the North Fork Stony Creek and Rancheria Reservoir on the main stem of Stony Creek would provide over 8 maf of storage for surplus water of the upper Sacramento River. The two-compartment Glenn Reservoir was conceived as terminal storage for exports from the North Coast rivers. Following passage of the Wild and Scenic Rivers Act of 1972, it was reformulated for offstream storage of water diverted from the Sacramento River. The unit cost of storage appeared reasonable, but controversy over diversions to the Tehama-Colusa Canal cast doubt on the environmental feasibility of diverting large flows to support the large-scale Glenn Reservoir. At this time, a large Glenn Reservoir does not appear to be a likely candidate for early construction. The smaller Thomes-Newville Reservoir (1.4 to 1.9 maf) operated as an offstream storage reservoir remains a possibility.

The third very large offstream storage option involves a new concept that has not been investigated in detail. The fundamental premise is sound: divert surplus water directly from Lake Shasta to an enlarged Clair Engle Reservoir on the Trinity River. This would reap some benefits of enlarging Lake Shasta without the associated major disruptions or relocation costs. The less attractive aspects include a 13-mile tunnel, a 1,500-foot pump lift, and substantial energy costs. This option appears to be more costly than enlarging Lake Shasta, but within the range of consideration. More information on environmental aspects would be needed for a better assessment. Experience has shown large projects at this stage often harbor unexpected environmental drawbacks. Currently, enlarging Clair Engle Reservoir is characterized as a future possibility, but not yet thoroughly explored.

The other very large offstream storage options, Sites and Colusa reservoirs, are related, in that the 3 maf Colusa Reservoir represents a northward expansion of the 1.2 to 1.8 maf Sites Reservoir into the Hunter and Logan creek basins. Either version of the reservoir would involve minimal environmental impacts within the area of inundation. The drawback is diverting surplus water from the Sacramento River for storage. Past proposals have focused on off-season use of the existing Tehama-Colusa Canal diversion facilities at Red Bluff Diversion Dam and the

Glenn-Colusa Irrigation District pumping plant near Hamilton City. Alternative Sites/Colusa conveyance facilities are now being examined. Although the alternative conveyance facilities would likely raise costs, the Sites and Colusa offstream storage options remain the most promising.

Large Offstream Reservoirs (0.5 to 1.0 maf). Deer Creek Reservoir in northeastern Sacramento County is the only North-of-Delta offstream storage option within this size range. Past investigators have examined a 0.6-maf Deer Creek Reservoir to store surplus water from the American River, delivered from an enlargement of the existing northern reaches of the Folsom South Canal. Another version of the project was considered for flood control, incorporating a gravity diversion direct from Folsom Lake via a new outlet at Mormon Island Dike. Major offstream storage in the Deer Creek area would be ideally suited to develop some of the abundant surplus flow of the American River without the difficulties associated with Auburn Dam. Also, by diverting directly from Folsom Lake or Lake Natoma, this project would avoid the principal conflicts with anadromous fish. Initial studies indicate a Deer Creek offstream storage project would be expensive--with a unit storage cost several times that of the lower-cost options.

Small to Medium Offstream Reservoirs (0.1 to 0.5 maf). Two options fall into this range, the Red Bank Project and Clay Station Reservoir. The Red Bank Project would consist of a 100 taf Dippingvat Reservoir and a 250 taf Schoenfield Reservoir. Dippingvat Reservoir would store water from the South Fork of Cottonwood Creek. Water would be diverted from Dippingvat to Schoenfield Reservoir where it would later be released down Red Bank Creek to the Sacramento River. Water could also be released via a new conveyance facility to the Corning Canal or the Tehama-Colusa Canal.

The Clay Station Reservoir is a smaller version of Deer Creek Reservoir, but 8 miles south. Its storage cost would be similar to Deer Creek's (very high). With its small size and high cost, Clay Station Reservoir offers little promise as a statewide water supply development.

Recommended Onstream and Offstream Surface Storage Options Upstream of the Delta. Figure 6-2 shows the location of recommended surface storage options upstream of the Delta. This reappraisal of surface reservoir options identified several that appear to offer the best prospects. Foremost in this group, in order of size, are:

- Colusa Reservoir, 3.0 maf offstream

- Thomes-Newville, 1.4 to 1.9 maf offstream
- Sites Reservoir, 1.2 to 1.8 maf offstream
- Dutch Gulch Reservoir, 0.7 to 0.9 maf onstream (or its upstream alternative, Fiddlers Reservoir, 0.2 to 0.5 maf)
- Tehama Reservoir, 0.5 to 0.7 maf onstream
- Wing Reservoir, 0.25 to 0.5 maf onstream (with Battle Creek diversion)
- Red Bank Project, 0.35 maf onstream and offstream
- Millville Reservoir, 0.1 to 0.25 maf onstream

A second tier of options offers substantial water supply potential, but with greater environmental impacts and/or economic costs that create some uncertainty about their practicability. From a flood control standpoint, enlarged Shasta, Auburn, and enlarged Millerton would provide important benefits. These include:

- Enlarged Lake Berryessa, up to 11.5 maf additional offstream
- Lake Shasta Enlargement, up to 10 maf additional onstream
- Glenn Reservoir, 6.7 to 8.7 maf offstream
- Auburn Reservoir, 0.85 to 2.3 maf onstream
- Thomes-Newville Plan, 1.4 to 1.9 maf onstream
- Deer Creek Reservoir, 0.6 maf offstream
- Enlarged Millerton Lake, 0.5 to 0.9 maf additional onstream
- Enlarged Folsom Lake, 0.37 maf additional onstream

A third group of options includes some that appear to offer viable alternatives, but for which limited information is available. These might be characterized as "worthy of a second look" in the future:

- Blue Ridge Reservoir, 0.95 maf onstream
- Nashville Reservoir, 0.9 maf onstream
- Kosk Reservoir, 0.8 maf onstream

Figure 6-2. Location of the North of Delta Reservoir Sites

Illustrative Operation Example. Additional surface storage upstream of the Delta would be effective if operated with major water supply reservoirs in the basin, principally Shasta Lake, Lake Oroville, and Folsom Lake. Under California's water rights hierarchy, new facilities may store surplus water that is not needed to meet preexisting rights. Since virtually no surplus water is available during the irrigation season, storage in new projects will be limited to late fall, winter, and early spring. Most storable flow occurs during periods of flood runoff. But, under certain conditions, coordinated operation with other reservoirs may allow occasional storage of fall releases made to achieve mandatory flood reservations.

A Sites Reservoir offstream storage facility provides a good example of how a Sacramento Valley surface project could be operated in coordination with other facilities. A large Sites Reservoir would provide 1.8 maf of storage in the foothills west of Maxwell. The large Sites Reservoir would be formed by constructing two main dams on Stone Corral and Funks creeks and several smaller saddle dams along the low divide between Funks and Hunters creeks. A larger Colusa Reservoir, providing 3.0 maf of storage, would be formed by extending the large Sites Reservoir north into the Hunters and Logan creek drainages.

In this configuration, water would be delivered to the reservoirs by winter use of the existing Tehama-Colusa Canal (which diverts from the river near Red Bluff), and by diversion to the Glenn-Colusa Irrigation District Canal at its pumping site near Hamilton City. A new pumped inter-tie would deliver the GCID canal water to the Tehama-Colusa Canal, from which it would be lifted a maximum of about 320 feet to Sites/Colusa reservoirs. In a recently conceived alternative, use of the existing diversions would give way in favor of a single pumping facility south of Chico Landing.

Most of the water available for storage in Sites/Colusa reservoirs occurs from December through April. Whenever water and energy were available, operators would make maximum effort to fill Sites/Colusa reservoirs. As seasonal water demands increased, water would be withdrawn from system reservoirs to meet needs. Since water would have to be pumped to Sites/Colusa reservoirs, the optimum operation would favor making the initial withdrawals from onstream reservoirs with higher ratios of inflow to storage (which are more likely to refill in the subsequent wet season). At some point, depending on the dryness of the year and the storage status of other facilities, withdrawals would be made from Sites/Colusa reservoirs. To minimize potential impacts of the existing diversions on the Sacramento River fisheries, Sites/Colusa reservoirs would release water back into the two canals in exchange for reduced diversions from the river. Sites/Colusa reservoirs would be drawn to minimum pool only in a prolonged series of drought years. In wetter periods, it would operate within a narrow range near full.

Off-Aqueduct Storage South of the Delta

Off-aqueduct storage south of the Delta has been investigated for many years. The CVP and SWP projects operate by releasing water from upstream reservoirs, which flows through the Delta and is diverted by the projects' pumping plants located in the south Delta. Storage south of the Delta is provided by San Luis Reservoir, a joint SWP/CVP facility in the San Joaquin Valley. Water pumped at the Banks and Tracy Pumping Plants is transported to San Luis Reservoir during the winter and early spring and later delivered to agricultural and urban water contractors. Additional storage south of the Delta would increase water availability through greater capture of surplus winter runoff, as well as provide for greater flexibility in operating the projects.

Dependable water supplies from the SWP are estimated at about 3.3 and 2.1 maf annually for average and drought years, respectively. Operation studies show that under 2020 level of demand, there is a 20 to 25 percent chance of delivering full entitlement in any given year with existing facilities (see Chapter 3 for a discussion on SWP operations). Additional off-aqueduct storage south of the Delta would increase SWP water supply reliability. CVP water delivery capability to its agricultural and urban contractors has been reduced by the CVPIA, which reallocated 800,000 af/year of project water to fisheries in Central Valley streams, about 200,000 af/year to wildlife refuges in the Central Valley, and about 120,000 af/year to increase flow in the Trinity River. As a result, CVP contractors will experience more frequent shortages. Additional off-aqueduct storage in the San Joaquin Valley is an option for USBR to increase CVP reliability for its Delta export service area.

In addition to increasing water supply reliability for both projects, more off-aqueduct storage south of the Delta would allow flexibility in pumping from the Delta. This flexibility would allow for shifting of Delta pumping toward months when the impacts of Delta diversions on fisheries are at their lowest. Having additional storage south of the Delta would allow projects to operate efficiently by taking advantage of times when maximum pumping is permissible.

Operation of the SWP and CVP is governed by several limiting factors including available water supplies, demands on this supply by the contractors, Delta water quality standards, instream flow requirements, and conveyance capability. The availability of water supplies throughout the system varies with natural conditions and upstream development. Winter floods can produce Delta flow rates of up to several hundred thousand cfs, while summer rates can be as low as a few thousand cfs. Annual Delta inflow varies substantially, ranging from more than 70 maf in wet years to less than 7 maf in drought years.

History of South of the Delta Off-aqueduct Storage Investigations. Since the 1950s, alternative off-aqueduct storage reservoir sites south of the Delta have been investigated by the Department. An agreement between the state and federal governments was signed in 1961 for construction and operation of San Luis Reservoir, a joint-use offstream storage facility that was completed in 1968. Before completion of San Luis Reservoir, it was recognized that additional storage south of the Delta was needed. As a result, a Delta storage development program was authorized by a legislative action in 1963-64, and work started to analyze the remaining potential off-aqueduct storage sites in the Central Valley. Under this program a cursory examination of potential sites identified the Kettleman Plain, Los Banos, and Sunflower sites for more in-depth study. Kettleman and Sunflower reservoir sites were dropped after reconnaissance level review because of their physical characteristics. The Los Banos site was deemed satisfactory for further study, and a 1966 report recommended additional geological exploration.

In the 1970s, a Delta alternatives study reviewed all drainages south of the Delta and selected Los Vaqueros, Los Banos Grandes, and Sunflower reservoirs for further studies. In a 1976 Delta Alternatives Memorandum Report, the Sunflower site was again eliminated when compared with the other sites on the basis of low storage availability and marginal foundation conditions. The Los Vaqueros site in Contra Costa County was included in the Department's proposed Delta program and was part of a comprehensive water management program proposed for authorization via 1977-78 legislation. (LBG was an alternative to Los Vaqueros in that legislation.) After that legislation failed passage, Los Vaqueros was included with the Peripheral Canal in SB 200. LBG was not specifically mentioned in SB 200, but the bill provided for additional off- aqueduct storage south of the Delta. In 1980, SB 200 was signed into law, but was overruled by voters in the 1982 general election.

The Department initiated a more comprehensive investigation of alternative off-aqueduct storage reservoirs south of the Delta in 1983, and after an initial examination of 18 storage sites, completed a reconnaissance report on 13 potential San Joaquin Valley sites. The study recommended that LBG be investigated to determine its most cost- effective size, and its engineering, economic, financial, and environmental feasibility. In 1984, the Legislature unanimously approved Assembly Bill 3792, authorizing LBG as a facility of the SWP. The Department released a Draft EIR and a feasibility report on LBG in 1990.

Since the 1990 reports, increased restrictions on Delta pumping and rising costs have prompted reconsideration of the LBG proposal. Given the uncertainty of future Delta exports and the reluctance of some SWP contractors to participate in the project, the Department reevaluated the feasibility and optimal size of additional off-aqueduct storage. A subsequent *Alternative South-of-the-Delta Offstream Reservoir Reconnaissance Study* identified all alternative reservoir sites south of the Delta by cursory examination of all topographic possibilities.

Evaluation of South of the Delta Storage Options. In the most recent *Alternative South of the Delta Offstream Reservoir Reconnaissance Study*, all geographically possible off-aqueduct reservoir sites on the west side of the San Joaquin Valley were identified (Figure 6-3). Alternatives on the east side of the valley were not considered due to the excessive cost of conveyance connections to the California Aqueduct. Ninety-seven dam sites in 46 watersheds were evaluated (Table 6-13) for their potential to economically improve SWP water supply reliability with minimal environmental and social impacts. For each potential reservoir site, the capital cost and the potential environmental impacts were evaluated and rated at a general level to determine the sites that should be studied in more detail.

Figure 6-3. Location of the South of Delta Reservoir Sites

Table 6-13. Watersheds Identified for South of Delta Reservoirs

Watershed	County	Watershed	County
Arroyo Ciervo	Fresno	Los Banos Creek	Merced
Arroyo Hondo	Fresno	Los Gatos Creek	Fresno
Bitter Creek	Kern	Los Vaqueros	Contra Costa
Bitterwater Valley	Kern/San Luis Obispo	McKittrick Valley	Kern
Broad Creek	Kern	Moreno Gulch	Fresno
Buena Vista Creek	Kern	Mustang Creek	Merced
Buena Vista Lake Bed	Kern	Orestimba Creek	Stanislaus
Cantua Creek	Fresno	Ortigalita Creek	Merced
Capita Canyon	Fresno	Oso Creek	Stanislaus
Castac Valley	Kern/Los Angeles	Packwood Creek	Kern
Deep Gulch	San Joaquin	Panoche Hills	Fresno
Del Puerto Canyon	Stanislaus	Panoche/Silver Creek	Fresno/San Benito
Garzas Creek	Stanislaus	Pleito Creek	Kern
Hospital Creek	San Joaquin/Stanislaus	Quinto Creek	Merced/Stanislaus
Ingram Canyon	Stanislaus	Romero Creek	Merced
Ingram/Kern Canyon	Stanislaus	Salado Creek	Merced
Kellogg/Marsh Creek	Contra Costa	Salt Creek	Fresno/Kern/Merced
Kern Canyon	Stanislaus	San Emigdio Creek	Kern
Kettleman Plain	Kings	San Luis Creek	Merced
Laguna Seca Creek	Merced	Sandy Creek	Kern
Little Panoche Creek	Fresno	Santiago Creek	Kern
Little Salado/Crow Creek	Stanislaus	Sunflower	Kings/Kern
Lone Tree Creek	San Joaquin	Wildcat Canyon	Merced/Fresno

The Department's study examined a wide range of storage volumes to evaluate potentially feasible projects based on the future long-term availability of exports from the Delta and the level of SWP contractor participation. Multiple reservoir sizes were considered for each alternative dam site. Volumes from 0.1 to 2 maf of storage were classified into four categories (Table 6-14).

Table 6-14. South-of-the-Delta Offstream Reservoir Size Categories

Category	Storage Volume (maf)
Small	0.1 - 0.25
Medium	0.25 - 0.5
Large	0.5 - 1.0
Very Large	1.0 - 2.0

All sites were evaluated using the same level of detail for each of the screening criteria. To evaluate and compare engineering characteristics, site information was gathered and construction costs were estimated for each alternative. For this purpose, a basic design configuration was selected. The storage capacity and water surface area of each reservoir option were calculated. The embankment volumes of each main dam and associated saddle dams were calculated.

The capital costs of all reservoir options were based on previous cost estimates developed for LBG facilities. Sixteen categories of cost, including mitigation costs, were calculated. A rating of the alternatives was performed based on estimated capital costs per acre-foot of storage. A unit storage cost of above $3,000 per acre-foot was deemed impractical and used as a threshold for deferring alternative sites. After deferring alternatives with unit storage costs above the practicable threshold, 33 dam sites in 18 watersheds were retained for further consideration. The unit storage costs for each of these options was translated to a 100 point system, with 0 points assigned to a unit cost of $3,000 per acre-foot of storage and 100 points to a unit cost of $0 per acre-foot of storage. Unit costs and scores were developed for several reservoir sizes at each dam site to cover the potential range of storage volume available at each dam site. The unit costs and scores for the reservoir sizes evaluated at each dam site were plotted versus volume. Curves were drawn through the points associated with each dam site to allow interpolation of this information for the entire range of storage volumes available at each dam site.

Environmental criteria were developed by the Department and the DFG. Factors affecting the degree of environmental sensitivity of each alternative reservoir site were identified by the Department and DFG, and reviewed by the USFWS. Six environmental screening criteria were developed. The environmental resources information varied among the sites. To ensure that all the options were evaluated equally, all sites used the same level of detail for each of the screening criteria. In evaluating wetland resources, USFWS National Wetland Inventory Maps were used to determine wetland abundance and types at each site. USGS national aerial photographic project maps were used to determine vegetation community abundance and type, and to obtain additional habitat and land use information. Listed and candidate animal and plant species that could potentially be found at the alternative sites were identified by searching the 1995 DFG Natural Diversity Data Base, the fifth edition of the California Native Plant Society's inventory of rare and endangered vascular plants of California, and DFG Wildlife Habitat Relationships System publications.

Economic and environmental sensitivity scores were given equal weight and combined to develop a score for each alternative reservoir site ranging from 0 to 100 points. Appendix 6B shows the combined rating of each alternative reservoir site, sorted by the four storage volume categories. Alternative reservoir sites with the highest scores were selected for each storage volume category. A minimum of 4 and a maximum of 10 alternative reservoir sites were chosen for each size category to provide a reasonable variety of alternatives for further evaluation. Using the previously defined categories, 10 small, 10 medium, 10 large, and 4 very large reservoir sites were selected for further evaluation. Many of the alternative reservoir sites were selected in more than one size category. A total of 18 reservoir sites in 10 watersheds were retained for more analysis after the initial evaluation (Table 6-15).

Table 6-15. Retained Watersheds

Alternative South of the Delta Offstream Reservoir Study

Phase One Overall Selections

Watershed	Dam Site	Reservoir Size Category			
		Small	Medium	Large	Very Large
Garzas Creek	104		X	X	X
	105		X	X	
	106	X	X		
	107	X			
	109			X	
Ingram Canyon	37		X	X	
Kettleman Plain	99	X			
LBG/Los Banos Creek	181	X	X	X	X
Little Salado/Crow Creek	63	X			
Orestimba	170		X	X	
	171		X	X	X
Panoche/Silver Creek	111	X			
	112		X	X	
	114	X	X	X	X
	45			X	
Quinto Creek	54	X			
Romero Creek	56	X			
Sunflower	177		X		

Recommended Storage South of the Delta. After a general evaluation, five sites appeared most favorable: Garzas Creek, Ingram Canyon, Los Banos Creek, Orestimba Creek, and Panoche/Silver Creek. As all past studies have shown, Los Banos Creek is the most cost-effective reservoir option considered for size categories above 250,000 af. The next least costly reservoir option ranges from about 50 percent more expensive for the medium size category up to about 100 percent more expensive for the very large category. In the environmental analysis, however, the Los Banos Creek option received the lowest environmental sensitivity rating (or had the most potential impacts) of all alternative sites. (This could be because there is a greater level of knowledge about this reservoir site.) Los Banos Creek was the highest ranked reservoir option based on total combined rating for reservoir sizes above 250,000 af.

A reservoir at Little Salado-Crow Creek would have a high surface area to storage volume ratio. There would be high evaporation losses, making the site unfavorable. Sunflower

Reservoir site lies 10 miles west of the California Aqueduct and would require an extended conveyance system. Significant seepage rates would also be expected at this site. These two sites (in addition to Romero Creek, Kettleman Plain, and Quinto Creek) have small storage capacities. Preliminary modeling results indicate that the range of additional surface storage south of the Delta should be around 500,000 to 2,000,000 af. The cumulative environmental impacts of several small to medium reservoirs needed to attain the storage capacity would probably be greater than one larger reservoir. Therefore, the small to medium size reservoir options were deferred.

Enlarging San Luis Reservoir has been considered for additional storage, but because of engineering and economic criteria, this has been deferred. The integrity of an enlarged San Luis Dam has been questioned, and the cost would be high.

These sites identified in the Department's review of south-of-Delta storge alternatives are being evaluated in the CALFED Bay-Delta program. Since CALFED has not yet finalized the components of its overall storage plan, we have used a placeholder in the Bulletin for the volume of storage, both north and south of the Delta, that the program might develop.

Operation of Off Aqueduct Storage South of the Delta. To illustrate how south of the Delta offstream storage would operate, the LBG Reservoir is used here as a model: This example treats LBG as an SWP facility. To meet CVP service area needs, USBR could participate with the Department in this project.

The LBG facilities would be located on Los Banos Creek 6 miles west of the California Aqueduct in the Los Banos Valley area. The main damsite would be about 80 miles south of the Delta. The facilities would consist of a storage reservoir with associated pumping-generating plants and conveyance channels. Delta winter flows would be conveyed through the California Aqueduct and pumped into LBG Reservoir for storage. Operation of LBG Reservoir would be similar to that of the existing San Luis Reservoir, except that LBG would retain about one half to two- thirds of its storage in average years to improve drought year water supply reliability of the SWP.

During periods of low Delta inflow, LBG would provide water supplies south of the Delta to reduce the demand for Delta exports. Added flexibility could permit the SWP to take advantage of seasonal and short-term water quality improvements to enhance the quality of delivered supplies. The 1.73 maf LBG Reservoir examined in the 1990 feasibility study would operate through a range of about 550 to 750 taf each year, filling in the early spring and releasing water to the California Aqueduct between May and September.

In-Delta Storage

A private developer has proposed a water storage project involving four islands in the Sacramento-San Joaquin Delta. The project would divert and store water on two of the islands (Bacon Island and Webb Tract) as reservoir islands, and seasonally divert water to create and enhance wetlands for wildlife habitat on the other two islands (Bouldin Island and Holland Tract). The developer would improve and strengthen levees on all four islands and install additional siphons and water pumps on the perimeters of the reservoir islands.

The project would divert surplus Delta inflows, or would manage transferred or banked water for later sale and/or release for Delta export or to meet Bay-Delta water quality or flow requirements. The reservoir islands would be designed to provide a total estimated initial capacity of 238 taf, 118 taf from Bacon Island and 120 taf from Webb Tract, at a maximum pool elevation of +6 feet relative to mean sea level.

A draft EIR/EIS for the Delta Wetlands Project was completed in September 1995. Water rights hearings on the project were held before the State Water Resources Control Board in 1997. Major issues included water quality concerns, levee integrity, and fishery impacts. The Board is currently reviewing and evaluating the evidence to develop a draft decision.

Groundwater And Conjunctive Use

Groundwater storage programs are not new in California. Conjunctive use programs have existed in California since at least the early 1900s. Each program has been designed for the political, institutional, legal and technical realities of the basin and the organizations involved. Conjunctive use in San Joaquin Valley usually involves importing a water supply to recharge empty aquifers, or to provide surface water for irrigation in lieu of groundwater. Such programs have been operated by local agencies for many years. In the Sacramento Valley conjunctive use programs must be designed differently. In the Sacramento Valley most of the aquifers are full. Conjunctive use programs would require that an aquifer be emptied, a source of water for recharge be identified, and recharge and extraction facilities be built.

The potential sustainable water supply that could be derived from groundwater storage is constrained by the water available to recharge that storage, the available storage capacity, and the wheeling capability of the conveyance facilities. In most areas the sources of recharge are (1) natural percolation from overlying streams, (2) infiltration of precipitation, (3) deep percolation of applied irrigation water, and (4) seepage from irrigation canals and ditches. In some areas, these sources are augmented by artificial recharge via spreading basins.

Potential for Conjunctive Use in the Central Valley

Plans for local development of additional groundwater and conjunctive use are covered under the regional discussions in Chapters 7 through 9. This section reviews the potential for groundwater development and conjunctive use as elements of statewide water management, concentrating on the potential for augmenting the supplies of the major State or federal water projects. As noted earlier, conjunctive use programs are also a component of CALFED's storage evaluations. No decisions have yet been made as to how water supply generated from a CALFED program might be allocated.

Sacramento Valley. As noted in the discussion of development of new surface storage reservoirs, the Sacramento River basin constitutes most of the potential for additional water development to meet statewide demands. Just as surface storage reservoirs are being evaluated to develop a portion of the basin's surplus runoff (about 9 maf), managed conjunctive use programs are being evaluated to the same end.

Although there is a tendency to think of Sacramento Valley groundwater in terms of a homogeneous underground reservoir that fluctuates gradually with wet and dry cycles, the reality is more complex. While much of the Sacramento Valley groundwater basin is interconnected, aquifer structure is far from uniform and horizontal movement of groundwater is slow. There can be differences in groundwater conditions from one area of the valley to another. Even within a small subarea, groundwater resources can range from abundance to scarcity within a few miles.

Potential conjunctive use programs must be evaluated on a site-specific basis, just as surface water storage facilities are evaluated. In concept, Sacramento Valley conjunctive use programs would operate by encouraging existing surface water diverters to make greater use of groundwater resources during drought periods. The undiverted surface water would become available for other users. The groundwater extractions would be replaced during subsequent wetter periods, through natural recharge, direct artificial recharge, or in-lieu recharge (supply of additional surface water to permit a reduction of normal groundwater pumping).

An example of an application of this approach was the Drought Water Bank. In 1991, 1992, and 1994, the DWB executed several contracts to compensate Sacramento Valley agricultural districts for reducing their diversions of surface water. Most of the reduced surface water diversions were made up by individual agricultural water users increasing their groundwater extractions from existing wells. A majority of the water derived through this groundwater substitution came from contracts with agencies in southern Butte County that hold pre-1914 surface rights for diversion of Feather River water. The 1994 program in this area was the largest, amounting to approximately 100,000 af. The DWB program included a groundwater monitoring component to evaluate the effects of increased extractions on neighboring non-participating groundwater users. Such monitoring programs would be an important component of future conjunctive use programs.

San Joaquin Valley. Potential conjunctive use projects in the San Joaquin Valley would entail refilling empty groundwater storage space for later withdrawal. Although aquifer storage capacity is available (over 50 maf), there is limited opportunity for conjunctive operation, due primarily to the lack of water for recharge. Even with Delta improvements, prospects for additional groundwater conjunctive use storage south of the Delta are limited. From the standpoint of statewide water supply, the areas of conjunctive use potential are those within reach (either directly or through exchange) of the California Aqueduct or CVP facilities. Examples of projects studied in the past include the Kern Water Bank and the Stanislaus River Basin and Calaveras River Water Use Program.

The Kern Water Bank project, described in Chapter 8, was initially developed by the Department and was subsequently turned over to Kern Water Bank Authority. The KWB is discussed as a local water management option for the Tulare Lake region in Chapter 8.

The Department and the USBR, in coordination with local agencies, evaluated the possibility of a conjunctive use project in the Stanislaus/Calaveras River basin. In 1986, SEWD and CSJWCD approached the Department and USBR with a conjunctive use proposal for their CVP contracts for interim water supply (which total 155 taf/year). The districts would divert CVP surface water supply in wet years and would revert to pumping groundwater and diverting

South Gulch Reservoir supplies in dry and critically dry years. Water would be stored in the proposed South Gulch Reservoir, an offstream storage reservoir near the Calaveras River, during wet years. Under this proposal, in dry and critically dry years the districts would allow the water to be released down the Stanislaus River for fishery needs, water quality improvement in the southern Delta channels, and CVP and SWP water supply improvement. However, enactment of CVPIA and SWRCB Order WR 95-6 requirements substantially reduced the quantities of surface water available to SEWD and CSJWCD. It is unlikely that water will be available for use outside the basin because of these requirements. The Department has deferred further participation in this program as a source of SWP supply.

Recent Groundwater Studies with Statewide Scope

The Department is carrying out a planning program to evaluate conjunctive use opportunities that could provide future water supplies for the SWP. USBR suggested that conjunctive use could be a major option for CVP water users in its 1995 report to Congress, "Least-Cost CVP Yield Increase Plan." CALFED is evaluating conjunctive use opportunities as part of examining additional storage north and south of the Delta.

SWP Conjunctive Use Studies. The Department's investigation of the conjunctive use potential of the Sacramento Valley for additional SWP supply is following three parallel tracks. The first is evaluation of the legal and institutional framework to define potential projects and their limitations. Second is an inventory of water supply infrastructure, water use, and hydrogeologic characteristics of the valley to identify areas most suitable for conjunctive use projects. The third track is pre-feasibility investigations of specific potential projects. Where appropriate, these studies recommend more comprehensive feasibility studies, or development of small scale demonstration and testing projects. An example of one such project under evaluation, the American Basin conjunctive use project, is discussed in the accompanying sidebar.

American Basin Conjunctive Use Project

The American Basin conjunctive use project has completed the feasibility investigation phase and negotiations are underway with local project participants. If negotiations are successful, CEQA/NEPA compliance and permit acquisition will follow, with initial project operation estimated for 2001. The project area is in southeastern Sutter County, western Placer County, and northwestern Sacramento County. Local water purveyors participating in the project include:

South Sutter Water District
Natomas-Central Mutual Water Company
Pleasant Grove-Verona Mutual Water Company
Placer County Water Agency

This project would develop about 55,000 af of water during drought periods to supplement diminished SWP surface water supplies. As proposed, the project would extend to 2035.

Three of the four project participants have a surface water supply within the project area from either the Bear or Sacramento River systems, and one relies on groundwater. SSWD's main surface water supply is from Camp Far West Reservoir on the Bear River. The reservoir provides about half the water supply, with groundwater providing the other half. Both NCMWC and PGVMWC have water right settlement contracts with the Bureau of Reclamation and divert from the Sacramento River system. Their base supply and CVP contract water meets nearly all their water demands, although some groundwater is used in each agency's service area. The portion of PCWA's service area in the project area relies solely on groundwater to meet its irrigation needs. PCWA has sufficient surface water supplies from the American River system to meet water needs in the area, but the proposed project would provide PCWA with a more economical way to deliver surface water to the area.

Summarized below are the approximate average annual surface water and groundwater quantities used within the project area for each of the project participants.

Project Participant	Annual Surface Water Use	Annual Groundwater Use
SSWD	90,000 af	90,000 af
NCMWC	70,000 af	13,000 af
PGVMWC	18,000 af	10,000 af
PCWA	----	30,000 af

The 40-30-30 Index (see description in Chapter 3) would be used to determine when project recharge and recovery would occur. When the index is classified as above normal or wet (which occurs almost 50 percent of the time), project recharge would occur. Recharge would be accomplished by in lieu means, which would require delivery of SWP water to those in the project area that use groundwater. This would reduce demands on the aquifer system by about 20 percent, allowing groundwater storage to recover from incidental infiltration. Construction of new surface water facilities to deliver SWP water from the Feather River to each project participant's service area would be required.

When the index is classified as dry or critical, project recovery would occur by groundwater substitution. Groundwater substitution would involve each district foregoing part of its normal surface water supply, thereby leaving it in the river for use by others. Reductions in surface water supply would be supplemented by extracting groundwater that was placed in the aquifer system during previous recharge years. These dry and critical year hydrologic conditions occur nearly 30 percent of the time.

It is anticipated that not all of the water recharged would remain in the project area. Some water would be lost to streams and rivers and some would flow out of the project area into adjacent areas. To partially account for these project losses, the feasibility study includes a no project operation component when the index is classified as below normal. In essence, the project participants would operate as they do presently. By adding this component, there would be more project recharge years than project recovery years, leaving some of the recharge water in the basin to account for project losses.

One of the biggest issues facing any conjunctive use project in the Sacramento Valley is the real water issue. A conjunctive use project must develop water that would not be otherwise available, or else it would deplete Sacramento River flows, so that the net available water supply would be about the same. Preliminary modeling studies suggest that this conjunctive use project would create an additional water supply during dry periods. Additional work remains before reaching a definitive answer.

Least-Cost CVP Yield Increase Plan. The U.S. Department of Interior's 1995 yield increase plan described possible actions to increase the yield of the Central Valley Project. The plan, required by CVPIA, was to evaluate ways to increase CVP yield to replace the water supply CVPIA dedicated to fish and wildlife purposes. Conjunctive use was one possible action and offered the largest potential annual yield. The plan suggests the potential annual yield of conjunctive use programs using active recharge in the Central Valley would be over 800 taf.

A regional groundwater model characterizing the Central Valley, together with an accompanying database and other information regarding soil and aquifer characteristics, was used to identify potential sites for active recharge programs. Table 6- 16 lists potential yield estimates from the study. Yield estimates for active recharge programs were based on the availability of storm flows on adjacent rivers. Local water supply availability has almost always limited the potential of a particular site. Potential environmental impacts attributable to developable yield are uncertain. Implementation of conjunctive use options would require additional feasibility investigations

CALFED Conjunctive Use Component. CALFED is evaluating conjunctive use potential as part of its storage and conveyance refinement process. The CALFED conjunctive use program will not identify specific projects, but will attempt to identify statewide potential for groundwater development and provide technical support to local projects. The program, in the early stages of development, is using operations studies to estimate statewide water supply benefits of conjunctive use in the Sacramento and San Joaquin Valleys.

CALFED is defining operating rules and assumptions in order to evaluate potential water supply benefits. Conjunctive use storage is currently assumed to be 250 taf in the Sacramento Valley and 500 taf in the San Joaquin Valley. Groundwater withdrawl and recharge capacities of 500 cfs are being assumed. Finally, groundwater withdrawl is being assumed to take place only in dry and critical water years. Potential water supply benefits of the CALFED conjunctive use program have not been quantified at this time.

Table 6-16. CVP Yield Increase Plan Conjunctive Use Options

General Site Locations	Potential Source(s) of Water	Activity	Evaluated Capacity[a] (1,000 af)	Annual Yield[b] (1,000 af)
Region 1				
E. of Anderson	Upper Sacramento River	Active recharge	60	15
Region 2				
SW and W of Orland, Tehama-Colusa canal in vicinity	Upper Sacramento River	Active recharge	360	90
Within Glenn County	Groundwater	Developable yield		55
Region 3				
S of Chico, near Wheatland, E. Sutter Bypass, and NE of Rio Linda	Feather and Bear rivers and Dry Creek (north of Sacramento)	Active recharge	280	85
Within Yuba County	Groundwater	Developable yield		25
Region 4				
NW of Woodland and SW of Davis (near Dixon), Yolo Bypass nearby	Cache Creek, Sacramento River	Active recharge	120	30
Region 5				
NE of Galt, SE of Elk Grove, SE of Lodi, and S of Manteca	American (using Folsom S canal), Cosumnes, Mokelumne, Calaveras, and Stanislaus	Active recharge	400	185
Region 6				
NW of Volta and at Oro Loma	Delta Mendota Canal, California Aqueduct	Active recharge	275	200
Region 7				
N of Modesto	Stanislaus or Tuolumne rivers	Active recharge	100	20
Region 8				
E of Atwater, NE of Merced, W of La Vina, and NE of Red Top	Merced, Chowchilla, Fresno, and San Joaquin rivers	Active recharge	350	140
Region 9				
none identified				
Region 10				
N of Raisin City, S of Kingsburg, S of Hanford, W of Visalia, and SW of Tipton	Kings, Kaweah, and Tule rivers	Active recharge	unknown	125
Region 11				
W of McFarland, and SW of Bakersfield	Kern River, California Aqueduct	Active recharge	500	50

[a] Capacity is taken to be the amount of water that can be recharged and extracted over any area without causing a water level fluctuation of more than 30 feet compared to historic water levels and has been estimated using a large-scale regional model. Values are not maximums and are used for comparison purposes.

[b] Location(s) descriptions are reflective of general areas where active recharge programs were estimated to be feasible. Each reference to a city or town represents a single site (NW of Woodland and SW of Davis refers to two potential site areas). Many regions have multiple sites where active recharge is possible.

Water Transfers

Increasingly, water agencies are including transfers as components of their future resources mix -- not just as drought management techniques, but as a source of supply in normal water years. In fact, it is becoming increasingly common to see local agency plans with a menu of transfer alternatives which include one-time spot transfers, short or long-term agreements for drought year transfers, and long-term agreements for average year water transfers.

For Bulletin 160, water transfers are defined as water obtained from:

- The permanent sale of a water right by the water right holder. (Although common in other western states, this method of water transfer is used less frequently in California than the following methods.)
- A lease from the water right holder, who retains the water right, but allows the leaseholder to use the water under specified conditions over a specified time period.
- The sale or lease of a contractual right to water supply. The holder of a contractual right to water supply provided by a water right holder (e.g., CVP, SWP, other water wholesalers) transfers the contractual right, or use of the contractual right, an action usually requiring the approval of the water right holder.

A predominant concern with transfer proposals is that only real water is transferred, and that transfer of paper water is avoided. The difference is that real water involves a change in the place and type of an existing use, while paper water might involve transfer of water that was not otherwise going to be beneficially used during the period of the proposed transfer.

Several agencies have identified water transfers as potential water management options. For retained transfer option, Bulletin 160-98 water budgets show increases in supply for the gaining regions. However, the water budgets do not reflect corresponding reductions in demand in regions from which water is being transferred, unless specific participants are identified, and the transfers are large enough to be visible in the water budgets. Presently, the only transfers that fit this category are those associated with the Colorado River 4.4 Plan.

One of the larger potential water transfers identified in Bulletin 160-98 is CVPIA water acquisition for instream flows and wildlife refuges. As discussed in Chapter 4, Bulletin 160-98 shows a future environmental water demand for these acquisitions based on Alternative 4 of the 1997 CVPIA PEIS. (This demand is a placeholder pending a final decision as to the proposed scope of CVPIA's water acquisition program.) At this time, no long-term contracts for water transfers have been established -- supplemental water acquired to date has been purchased on a year-to-year basis. It is thus not possible to identify specifically how and where the supplemental water would be obtained in the future, or what other water demands might be reduced as a result of CVPIA water transfers. Therefore, Bulletin 160-98 water budgets do not show transferred water supplies corresponding to the CVPIA demands. Instead, the acquisition amount is shown as shortages in the Sacramento and San Joaquin regions.

Is That Real Water?

The initial rush of enthusiasm for water transfers stimulated much discussion about supposedly unused water. Some water users in the State hold rights (statutory or contractual) to more water than they currently use to meet their needs. Why not transfer those rights to others?

Such transfers looked attractive to both prospective sellers and buyers. The sellers would receive payment for something they were not using, while the buyers would meet urgent water needs. This view, however, overlooks the fact that water to meet the transferred rights has been part of the basin supply all along, and has almost always been put to use by downstream water right holders. This type of transfer became know as a "paper water" deal: the money goes to the seller, while the water is transferred to the buyer from the supply of an uninvolved third party.

A similar outcome can result from some water conservation measures. Changes in irrigation management can reduce drainage outflow that otherwise contributes to the supply of downstream users or meets an instream need. Proposals to transfer water saved through such drainage reduction can also represent paper water.

The California Water Code includes a number of provisions to regulate and facilitate water transfers (Water Code Sections 1435, 1706, 1725, 1736, 1810d), as well as a "no-injury" clause that prohibits transfers that would harm another legal user of the water. This clause is the basis for prohibiting transfers of paper water.

In analyzing water transfer and water conservation proposals, the Department uses the terms real water and new water to contrast with paper water. Real water is water not derived at the expense of any other lawful user, i.e., water that satisfies the Water Code's no injury criterion. New water is water not previously available, created by reducing irrecoverable losses or outflow to the ocean or inland salt sinks. New water, by definition, must be real, but not all real water is new. For example, water made available through land fallowing is real (because it reduces ETAW), but not new.

Sources of Water for Transfer

The increased attention to transfers following the 1987-92 drought brought clear recognition that water transfers alone do not create new supplies--they are a process by which supplies developed by other means are moved to a new place of use. In any water transfer agreement, the reliability of the supply acquired by the transferee depends upon the specific details of the transfer agreement and the relative priority of the water rights involved. With this approach, it is helpful to examine potential sources of water that have been most often considered for transfer.

- Land Fallowing. A potential source of water for transfer is to forego growing crops in a given area and move the water that would have been consumed to a different service area. Although there can be some difficulty in quantifying the amount of water made available and its impact on the economy of local agricultural communities, land fallowing is a proven demand management technique. Land fallowing may be undertaken on either a permanent basis (land retirement) or only during drought periods in various forms of shortage contingency programs. Drawbacks of fallowing include potential impacts on non-participating third parties.
- Crop Shifts. Some of the third party effects of fallowing could be reduced by substituting crops that consume less water for those that would use more. For example, safflower might be planted in place of tomatoes, or wheat in place of corn. The substituted crop is usually less profitable for the grower, so the potential transferee provides an appropriate incentive payment. Such arrangements can produce real water savings, but they introduce a further layer of complexity and uncertainty. (How can it be demonstrated that the higher water-using crop would really have been planted in the absence of the arrangement? And, what are the related effects on groundwater recharge and drainage contributions to downstream surface supplies?) Crop shift proposals were solicited by the Department for the 1991 Drought Water Bank, but played a limited role. Because crop acreage is market driven, the ability to do large scale crop shifts is limited. Crop shifts are thus expected to have a small role in water transfers.
- Water Conservation. Where conservation techniques result in real water savings (see sidebar), conserved water may be available for transfer to other users. Recent proposals for transfers of conserved water have mostly occurred in the agricultural sector, where considerable confusion has sometimes resulted over the distinction between reducing applied water and producing real water savings. Most of California's irrigated areas overlie

usable groundwater basins and are linked by networks of surface streams and drains. Water leaving one area usually contributes to the supply of other areas or, in the Central Valley, to necessary Delta outflow. Under such conditions, new water savings result only from reducing crop consumptive use, or other consumptive use, or from reducing losses to unusable saline sinks. From a statewide supply perspective, opportunities for transfer of conserved water occur primarily in areas such as the Imperial Valley, where agricultural drainage water flows to the Salton Sea. However, it must be recognized that the agricultural runoff entering the Sea supplies the relatively fresher water needed to sustain the Sea's biological resources. The ability to transfer conserved water that would otherwise flow to the Sea must take into consideration impacts of such transfer on the Sea.

From a local perspective, however, the situation may be different; for example, Sacramento Valley conservation measures that reduce agricultural drainage make more water available for use in the conserving area -- but at the expense of downstream users. Local districts in such areas have substantial incentive to practice conservation to improve the utility of their existing supplies, but the potential for creating real water for transfer to others is limited.

- Groundwater Substitution. Many California growers have rights and access to surface water supplies, even though their land may overlie productive groundwater basins. In such cases, a grower may agree to forego use of surface water rights for a period, substituting groundwater instead. The unused surface water then becomes available for transfer to other users. This technique was tested during the Drought Water Banks of 1991, 1992, and 1994. Under favorable conditions (where wells and pumps are already installed), it can produce considerable water for transfer on relatively short notice. One major concern with groundwater substitution is the potential impact on neighboring non-participating pumpers. Substantial monitoring to assure there are no unreasonable third party impacts is needed. Another consideration with groundwater substitution is that additional pumping may induce additional recharge that depletes usable streamflow; only that portion of groundwater replenished from future surplus flows is really a new supply. Additional experience will be needed to define the potential of this source, resolve concerns over impacts on nearby pumpers and regional surface supplies, and explore possibilities for construction of dedicated recharge facilities.

- Surface Storage Withdrawals. Existing reservoirs within California have a combined storage capacity on the order of 40 maf. These facilities are operated by a wide spectrum of entities, for a variety of water supply, flood control, power, and recreation objectives. At any given time, there is likely to be water stored somewhere in the system that is not planned to be released, but could be made available to meet urgent needs. Such withdrawals come at a price, however, usually a reduction of power generation or recreational usage, or increased risk of future water supply shortage. Payments to the reservoir owner implicitly include a component to compensate for reduced benefits, increased risk, and other costs. Surface storage withdrawals are easily quantified and clearly represent new water, provided the storage is refilled from future surplus flows. Storage withdrawals played an important role in recent transfers; the refill constraints were handled through a contract clause whereby reservoir owners agreed to defer refill until a time of future high runoff when there would be no detrimental effect on other water users. In the long run, the prospects for such transfers will tend to diminish as water demands increase in the reservoirs' primary service areas.

Prospects for Water Transfers

Water transfers will continue to play a role in meeting California's water needs, but there will be a continuing shift in emphasis toward systemwide appraisal of impacts and growing recognition of the need to protect the rights of all lawful users of water. Mechanisms for evaluation and approval of water transfers have been developed, and will likely continue to evolve. For example, USBR developed guidelines for implementing transfers of CVP water under the CVPIA, California Water Code directs the Department to facilitate voluntary exchanges and transfers of water, and 1992 changes to state law authorized water suppliers (local public agencies and private water companies) to contract with water users to reduce or eliminate water use for a specified period of time, and to transfer the water to other water suppliers and users.

The ability to carry out transfers is dependent on conveyance provided by California's existing rivers, canals, and pipelines. Agencies planning to use long-term transfers as part of their core water supplies must have access to reliable conveyance for these supplies. Major conveyance facilities now wheeling water for transfers include CVP and SWP facilities. A long-term Delta fix is essential for providing reliable conveyance of transferred supplies across the Delta. The California Water Code requires that public agencies make available unused conveyance capacity (see sidebar).

As more agencies are looking to water transfers as an option to balance demand and supply, the competition for water available for transfer will increase. Table 6-17 shows a few larger water supply programs and water suppliers and the amounts of transfers proposed in planning documents, to illustrate the magnitude of transfers being considered.

Water Code Section 1810 *et seq.*

Notwithstanding any other provision of law, neither the state, nor any regional or local public agency may deny a bona fide transferor of water the use of a water conveyance facility which has unused capacity, for the period of time for which that capacity is available, if fair compensation is paid for that use, subject to the following:

(a) Any person or public agency that has a long-term water service contract with or the right to receive water from the owner of the conveyance facility shall have the right to use any unused capacity prior to any bona fide transferor.

(b) The commingling of transferred water does not result in a diminution of the beneficial uses or quality of the water in the facility, except that the transferor may, at the transferor's own expense, provide for treatment to prevent the diminution, and the transferred water is of substantially the same quality as the water in the facility.

(c) Any person or public agency that has a water service contract with or the right to receive water from the owner of the conveyance facility who has an emergency need may utilize the unused capacity that was made available pursuant to this section for the duration of the emergency.

(d) This use of a water conveyance facility is to be made without injuring any legal user of water and without unreasonably affecting fish, wildlife, or other instream beneficial uses and without unreasonably affecting the overall economy or the environment of the county from which the water is being transferred.

Table 6-17 . Water Transfer Proposals (taf)

	Year	
	Average	Drought
Drought Water Bank	--	250
SWP Supplemental Purchase Program	--	200
CVPIA Interim Water Acquisition Program	365	365
Alameda County WC&FCD, Zone 7	50	50
Alameda County Water District	15	25
Contra Costa Water District	40	50
Santa Clara Valley Water District	100	100
Sacramento County Water Agency	30	30
Westlands Water District	200	200
Metropolitan Water District of Southern California	--	300
San Diego County Water Authority	200	200
Total	**1,000**	**1,770**

The following sections describe some specific water transfer proposals, where information is currently available to describe an established or proposed program. Many local agencies may intend to buy water on the spot market as needed to respond to service area demands, but do not have agreements or defined programs in place at this time.

Drought Year Transfers

Transfers Involving Conveyance in SWP Facilities

Drought Water Bank Program. The Department manages and implements the Drought Water Bank. The goal of the Drought Water Bank program is to meet critical water needs resulting from droughts or other unanticipated conditions. The DWB program is a water purchasing and allocation program whereby the Department will purchase water from willing sellers and remarket the water to buyers under specific critical needs allocation guidelines. The DWB's EIR established the DWB as a 5 to 10 year program. The program is intended as a short-term measure in near-emergency conditions due to lack of water.

Chapter 3 describes past Drought Water Bank activities. The quantities and prices of water made available in previous drought water bank programs through surplus reservoir releases, through groundwater substitution, and through land fallowing programs are summarized in Table 6-18 below. Past experience suggests that about 250,000 af of water per year could be allocated by the DWB in the future through similar programs.

Table 6-18. Drought Water Bank

Year	Purchase Price ($/af)	Source of Drought Water Bank Water: Surplus Reservoir Storage (af)	Groundwater Substitution (af)	Fallowing (af)	Total Sources (af)	Amount Allocated[1] (af)
1991	$125	147,332	258,590	414,743	820,664	389,970
1992	$50	31,705	161,541	0	193,246	158,768
1994	$50	33,000	188,754	0	221,754	173,483

[1] Amount allocated for urban, agricultural, and environmental uses. This represents the actual supply developed by the bank after conveyance and fish and wildlife requirements were met.

Supplemental Water Purchase Program. The Department is proposing a supplemental water purchase program to increase water supply reliability for State Water Project contractors. A draft EIR for the six-year program originally proposed the transfer of up to 400,000 af of water in drought years from a combination of (1) surface water which is replaced by additional groundwater pumping, and (2) reservoirs with temporarily surplus supplies. Such water would be purchased from willing sellers and provided to participating SWP contractors. After a number of public workshops, the Department has reevaluated the program and has eliminated the groundwater component. The maximum supply available for transfer would be 200,000 af a year without the groundwater component. The final EIR is expected to be released in mid-1998.

The proposed program would be in effect for 6 years and would be implemented only in years during which the Department was unable to deliver enough project water to meet contract entitlement requests. The program is intended to fill all or part of the shortfall between deliveries to the participating contractors and requests from those contractors up to their contractual entitlement for that year. The supplemental water would be provided through options or direct purchase agreements. The program would primarily use existing water production and transport facilities.

Transfers Sponsored by Local Agencies. Semitropic Water Storage District has developed a groundwater storage program with a maximum storage capacity of 1 maf and maximum annual extraction of 223 taf. Under this program, a banking partner may contract with Semitropic to deliver its available SWP water or other water supplies to Semitropic for in-lieu groundwater recharge. At the contractor's request, groundwater would be extracted and delivered to the California Aqueduct or pumped by SWSD farmers in exchange for SWP entitlement deliveries. Currently, MWDSC and SCVWD District each have long-term agreements with Semitropic for 350 taf of storage. ACWD is in the process of signing a similar agreement for 50 taf of storage. There is 250 taf of capacity available for other banking partners. Participants are not restricted to SWP contractors although access to the delivery system is necessary. This program, discussed in more detail in Chapter 8, is considered a transfer in this Bulletin because of the possible exchange of Semitropic's SWP entitlement for banked SWP water. If Semitropic enters into additional agreements restricted to physically storing water without a change in ownership of the water, they would not be considered a water transfer in this Bulletin. The costs of this water is about $175 per af.

An similar banking/transfer agreement has been proposed between Arvin-Edison WSD and MWDSC for up to 350 taf of storage in Arvin-Edison's groundwater basin. Up to 75 taf per year could be withdrawn and delivered to MWDSC through the California Aqueduct in drought years at a cost of about $155 per af.

Transfers Involving Conveyance in CVP Facilities. Historically, users of CVP water have made intra-district, and sometimes inter-district transfers of project supply. The 1992 enactment of CVPIA provided the authority to transfer project water outside of project boundaries to nonproject water users.

Transfers Among Project Water Users. The San Luis & Delta-Mendota Water Authority, which represents 32 urban and agricultural water districts on the west side of the San Joaquin Valley and in San Benito and Santa Clara counties, has developed an agreement that will help its members cope with water supply uncertainties. Under a three-way agreement between the Authority, SCVWD, and the USBR, participating member districts (shortage year providers) can receive some of SCVWD's federal water allocation in normal and above-normal water years in exchange for a share of the shortage year provider's federal allocation during water-short years. The agreement, which does not require any additional exports from the Delta, will be an internal reallocation of existing federal supplies to allow greater flexibility in meeting urban and agricultural water demands.

Specifically, SCVWD will provide 100,000 af of water within a 10-year period for reallocation by the USBR to shortage year providers. In exchange, shortage year providers will provide SCVWD with shortage year protection for as long as necessary by directing the USBR to reallocate the portion of their supplies (not to exceed an annual total of 14,250 af) needed to deliver no less than 97,500 af to SCVWD during years when the CVP's urban water deliveries are 75 percent or less of contract entitlement. As part of the agreement, SCVWD will optimize its use of non-CVP water supplies, which will benefit all CVP irrigation water service contractors in the Delta export service area.

Westlands Water District and San Luis Water District have already agreed to become shortage year providers; other Authority members may also enter into the agreement over time.

Transfer of CVP Water Outside Project Boundaries. The CVPIA authorized transfer of project water outside the CVP service area, subject to numerous specified conditions, including a right of first refusal by existing CVP water users within the service area. As of this writing, no transfers have either been approved or implemented under this provision. One transfer that had been discussed was a proposed transfer between Arvin-Edison WSD and MWDSC.

Colorado River Region

Future banking. In its 1996 session, the Arizona Legislature enacted HB 2494, establishing the Arizona Water Banking Authority. The Authority is authorized to purchase unused Colorado River water and to store it in groundwater basins to meet future needs. Conveyance to storage areas is provided by the Central Arizona Project. The legislation further provided that the Authority may enter into agreements with California and Nevada agencies to bank water in Arizona basins, with specific limitations. Under this legislation, future interstate banking in Arizona would have a maximum drought year yield of 100,000 af, with 50,000 af available to California.

Land Fallowing Programs. Land fallowing programs could be implemented to provide water for transfer to urban areas during drought periods, as demonstrated by one test program conducted in the Colorado River Region. In 1992, MWDSC began a two-year land fallowing test program with Palo Verde Irrigation District. Under this program, farmers in PVID fallowed about 20,000 acres of land. The saved water, about 93,000 af per year, was stored in Lake Mead for future use by MWDSC. (That water, however, was subsequently lost to MWDSC when flood control releases were made from Lake Mead.) MWDSC paid each farmer $1,240 per fallowed acre, making the costs of the water to MWDSC about $135 per af. It is expected that similar programs could be implemented in the future by agencies in the South Coast Region and Colorado River Region to provide about 100,000 af per year during drought years.

Every Year Transfers

Central Valley

Permanent Transfer of SWP Entitlement. The Monterey Agreement provides that 130,000 af of agricultural entitlements be sold to urban contractors on a willing buyer-willing seller basis. Several such transfers of entitlement have already been implemented. Kern County Water Agency permanently transferred 25,000 af of entitlement to Mojave Water Agency and is in the process of finalizing the permanent transfer of 7,000 af to Alameda County Flood Control and Water Conservation District, Zone 7. KCWA is also considering the permanent transfer of 9,097 af to Castaic Lake Water Agency.

Permanent Transfer of CVP Entitlement. As with the SWP, transfers of contractual entitlements among CVP contractors is now occurring. The CVP reallocation agreement represents a new approach to transfers among project water users.

CVPIA Interim Water Acquisition Program. Transfers of developed supplies for environmental purposes (where the transfer occurs as part of a willing buyer-willing seller arrangement, and not as the result of a regulatory action) are a relatively recent occurrence. Under the provisions of the CVPIA, an interim water acquisition program was established to be in effect from October 1995 through February 1998. Through this interim program, water is being acquired to meet near-term fishery and refuge water supply needs while long-term planning continues.

During the interim program, USBR could acquire up to 100,000 af annually on each of the Stanislaus, Tuolumne, and Merced rivers. Water acquired under the program would be used for a combination of instream fishery flows on the three tributary rivers, and for flow and water quality improvements on the San Joaquin River. The specific quantifies of water to be acquired each year and associated release patterns would depend upon projected flow conditions in the individual rivers, and projected flow and water quality conditions in the San Joaquin River at Vernalis.

Under this program, USBR would acquire up to 13,123 af of water annually from willing sellers in the Sacramento and Feather River basins to provide increased deliveries to wetland habitat areas in the Sacramento Valley. Likewise, up to 52,421 af would be purchased annually from willing sellers in the San Joaquin Valley to provide increased deliveries to wetland habitat areas in the San Joaquin Valley. It is anticipated that water would be made available from groundwater, groundwater substitution, transfer of unutilized contract entitlement, and/or conservation.

CVPIA AFRP Water Acquisition Program. The CVPIA provides for annual acquisition of water for AFRP instream flows under Section 3406(b)(3). The Act also provides for annual acquisition of water to meet Level 4 wildlife refuge deliveries under Section 3406(d)(1-2). The following CVPIA water acquisition alternatives were developed in the USBR's November 1997 Draft PEIS:

- Alternative 1: No water would be acquired to meet fish and wildlife targets.
- Alternative 2: AFRP water would be acquired annually from willing sellers on the Stanislaus (60 taf/yr), Tuolumne (60 taf/yr), and Merced (50 taf/yr) rivers and on the tributary creeks of the upper Sacramento River that support spring-run salmon populations. Acquisition amounts on the tributary creeks were not quantified in the PEIS. The acquired water would be managed to meet target flows for the streams. The acquired water also would be used to improve flows in the Delta. Therefore, the acquired AFRP water could not be exported by the CVP or SWP. In Alternative 2, refuge water would be acquired to provide the difference between Level 2 and Level 4 supply requirements. Annual water acquisitions in the Sacramento River, San Joaquin River, and Tulare Lake regions would be about 30 taf, 80 taf and 20 taf, respectively.
- Alternative 3: AFRP water would be acquired annually from willing sellers on the Yuba (100 taf/yr), Mokelumne (70 taf/yr), Calaveras (40 taf/yr), Stanislaus (200 taf/yr), Tuolumne (200 taf/yr), and Merced (200 taf/yr) rivers and on the tributary creeks of the Upper Sacramento River to improve instream flows in accordance with target flows. As in Alternative 2, acquisition amounts on the tributary creeks were not quantified in the PEIS. The acquired AFRP water would not be managed for increased flows through the Delta. Therefore, it could be exported if Order WR95-6 conditions were met. Under

Alternative 3, refuge water would be acquired to meet Level 4 requirements in the same quantities as described in Alternative 2.

- Alternative 4: AFRP water would be acquired annually for the streams as under Alternative 3. The acquired water would be managed to meet target flows for the streams and to improve flows in the Delta. Therefore, the acquired water could not be exported by the CVP or SWP. Refuge water would be acquired for delivery of Level 4 water supplies in the same manner as described in Alternative 2.

As discussed in Chapter 4, Alternative 4 was selected from among the PEIS alternatives as a placeholder for Bulletin 160-98 future CVPIA environmental water demands because it represents the most conservative estimate of future water supply requirements. The PEIS estimates a reduction of 142,000 acres of irrigated agricultural land would be needed to provide CVPIA water acquisitions under Alternative 4. Approximately 21,000 acres would be fallowed in the Sacramento River Region, 118,000 acres would be fallowed in the San Joaquin River Region, and 3,000 acres would be fallowed in the Tulare Lake Region. Since USBR has not yet identified specific proposals for transfers, we have not included the demand reduction resulting from this land fallowing in the Bulletin 160-98 water budgets. We show the Alternative 4 instream flows as a future environmental water demand in the budgets, which has the effect of increasing 2020 water shortages. (In the PEIS, USBR estimates that Alternative 4 water acquisition costs could be up to $120 million per year.)

Colorado River. Water agencies in the South Coast Region will continue to pursue programs to offset the reduction in existing supplies resulting from California reducing its use of Colorado River water to 4.4 maf. This subject is covered in detail in Chapter 9. A potential transfer is briefly summarized below.

San Diego County Water Authority and Imperial Irrigation District have been discussing a potential transfer of water saved due to extraordinary conservation measures within IID. The agencies executed a September 1995 MOU concerning negotiation of a transfer agreement, followed by development of proposed terms and conditions of a transfer. As originally proposed, an initial transfer of 20 taf would begin in 1999, with the annual quantity of transferred water increasing to 200 taf after 10 years. In order to transfer the acquired water, SDCWA (a member agency of MWDSC) must negotiate a wheeling agreement with MWDSC for use of capacity in MWDSC's Colorado River Aqueduct.

Water Recycling

The Department, in cooperation with the WateReuse Association of California, developed and conducted a 1995 water recycling survey as described in Chapter 3. Table 6-19 shows 1995 base level of water recycling and future projects in planning and conceptual stages. Projects in the conceptual stage are not yet defined and are deferred in this bulletin from further evaluation. The 1995 annual water recycling of 485 taf is expected to increase to 615 taf by 2020 due to greater production at existing plants and new production at plants currently under construction. By 2020, projects in the planning and design stages will add an additional 837,000 af of recycled water, providing almost 700,000 af of new water supply to the State. These projects are discussed as local water supply options in Chapters 7 through 9.

Table 6-19. Water Recycling Options and Resulting New Water Supply
(thousand of acre-feet)

Projects	Retain / Defer	1995		2020	
		Total Water Recycling	New Water Supply	Total Water Recycling	New Water Supply
Base		485	323	615	468
Planned	R			837	699
Conceptual	D			131	31

New water supply would be generated by water recycling where the outflow of water treatment plants would otherwise enter a salt sink or the Pacific Ocean. In the Central Valley and other inland communities, the outflow from waste water treatment plants is put into streams and groundwater basins and is generally reused. Recycling of such outflow would not generate any new supply.

In the South Coast Region, water agencies are concerned that the lack of future high-quality water for blending supplies, or the cost of desalination of recycled water, could affect implementation of future water recycling facilities. Because of these concerns, the MWDSC, USBR, SDCWA, and DWR have cooperated on a salinity management study. The study's initial phase focuses on identifying problems and salinity management needs of MWDSC's service area. This study is discussed in the South Coast Region of Chapter 7.

Table 6-20 shows 1995 base and projections of total water recycling and new water supply by hydrologic region. Total annual water recycling for 2020 is projected to increase from the 1995 level of 485 taf to about 1,452 taf. This would contribute almost 1.2 maf of new water to the State's supply. Two major water recycling programs being planned are the Bay Area Regional Water Recycling Program and the Southern California Comprehensive Water Reclamation and Reuse Study, discussed in detail in Chapter 7.

Table 6-20. Total Recycling and Resulting New Water Supply by Hydologic Region (taf)

Hydrologic Region	1995 Total Water Recycling	1995 New Water Supply	2020 Total Water Recycling	2020 New Water Supply
North Coast				
Base	13	13	13	13
Options			15	--
San Francisco Bay				
Base	40	35	40	35
Options			101	92
Central Coast				
Base	19	18	44	42
Options			40	38
South Coast				
Base	263	207	364	328
Options			640	569
Sacramento River				
Base	12	--	14	--
Options			6	--
San Joaquin River				
Base	37	--	39	--
Options			7	--
Tulare Lake				
Base	51	--	51	--
Options			25	--
North Lahontan				
Base	8	8	8	8
Options			--	--
South Lahontan				
Base	27	27	27	27
Options			3	--
Colorado River				
Base	15	15	15	15
Options			--	--
STATEWIDE TOTAL				
Base	485	323	615	468
Options			837	699
TOTAL RECYCLING			**1,452**	**1,167**

Desalination

Today California has more than 150 desalting plants providing fresh water for municipal, industrial, power, and other uses. The freshwater capacity of these plants totals about 66,000 af annually, a 100 percent increase since 1990. Common feedwater sources for desalting plants include brackish groundwater, municipal and industrial wastewater, and seawater. Groundwater recovery currently makes up the majority of desalting plant capacity, 45,000 af. Wastewater desalination accounts for 13,000 af and seawater desalting accounts for 8,000 af of total capacity.

Groundwater reclamation and wastewater recycling will be the primary uses of desalting in California in the foreseeable future. Improvements in membrane technology will spur considerable growth in these areas as discussed in Chapter 5. Seawater desalting is projected to grow very slowly. The use of desalination in wastewater treatment plants is a form of water recycling and is included in the water recycling section. This section will discuss the future potential for brackish groundwater and seawater desalination.

Groundwater Recovery.

High total dissolved solids and nitrate levels are common groundwater quality problems. Groundwater reclamation programs can be designed to recover mineralized groundwater or groundwater with nitrate contamination, as shown in the examples given in Chapter 5. Currently, most groundwater reclamation programs under consideration are located in the South Coast region (excluding groundwater reclamation solely to remediate contamination at hazardous waste sites). Some of the polluted water must be treated and some can be blended with fresh water to meet water quality standards.

The potential annual contribution of groundwater reclamation by year 2020 is about 100,000 af, with 93,000 af in the South Coast Region. Options are discussed in the individual regional chapters.

Seawater Desalination

The major limitation to seawater desalination has been its high cost, much of which is directly related to high energy requirements. Seawater desalting costs range from $1,200 to $2,000 per af; additional costs are required to convey the water to the place of use. With few exceptions, the combined costs are greater than costs of obtaining water from other sources. However, seawater desalting can be a feasible option for urban supplies for coastal communities that are relatively far form the statewide water distribution system and have limited water supplies. Because of such circumstances, seawater desalting plants have been constructed in the City of Avalon (Santa Catalina Island) and the Cities of Santa Barbara and Morro Bay. Seawater desalting plants can be designed to operate only during drought to improve water supply reliability, as is the case for Santa Barbara's desalter.

During the 1987-1992 drought, there were plans under consideration to install and operate several seawater desalting plants in the Central Coast and South Coast regions, including several very large distillation plants using waste heat from existing thermal power plants in the South Coast region. The total potential of the proposed plants was about 123,000 af per year. With the return to average water supply years, most of these plants have been put on hold. MWDSC's research distillation plant is the only (potentially) large non-reverse osmosis facility now under consideration.

MWDSC, in cooperation with the U.S. Government and the Israel Science and Technology Foundation, is in the process of completing final design of a 12.6 mgd demonstration desalination plant to evaluate a future full scale 60 mgd to 80 mgd seawater desalination plant. The technology is based on a multiple-effect distillation process which in part uses heat energy from an adjacent power plant. The goal is to demonstrate that the multiple-effect distillation process can produce desalinated seawater at a cost of less than $1,000 per af. If successful, a full scale plant could produce about 85,000 af per year.

Mission Basin Brackish Groundwater Desalting Research and Development Project

The Mission Basin groundwater desalting project is an example of the type of desalting projects likely to occur within the Bulletin's planning horizon.

The City of Oceanside owns and currently operates the Mission Basin Groundwater Desalting Facility. Under current operations, about 2,100 af per year of demineralized groundwater supply is produced from treating brackish groundwater through a reverse osmosis process. Because of the plant's successful operation over the past three years, the city plans to expand its production capacity up to 7,100 af, 22 percent of the city's yearly average demand. The cost of the expansion is estimated to be $7.5 million. The additional water supply is expected to be available by late 1999.

The Mission Basin aquifer holds about 92,000 af of water. The city anticipates that at least half of its future water supply can ultimately be derived from this source. Expansion of the Mission Basin Desalting Facility has several important benefits. It would provide the City of Oceanside an independent water source that can serve the community in the event of a natural disaster, such as an earthquake. In addition to reducing the city's reliance on imported water, the quality of water produced at the desalting facility is better than that of the city's imported source (total dissolved solids concentration of 400-500 mg/l versus 600-700 mg/l for imported water).

Weather Modification

Weather modification (cloud seeding) has been practiced in California for years. Most projects have been located on the western slopes of the Sierra Nevada and in parts of the coast ranges. Before the 1987-1992 drought, there were about 10 to 12 weather modification projects operating, with activity increasing during dry years. During the drought, the number of projects operating in California had increased to 20. However, some projects were subsequently dropped and others suspended operations as the winter turned wet.

Operators engaged in cloud seeding have found it beneficial to seed rain bands along the coast and orographic clouds over the mountains. The projects are operated to increase water supply or hydroelectric power generation. Although the amounts of water produced are difficult and expensive to determine, estimates range from a 2 to 15 percent increase in annual precipitation, depending on the number and type of storms seeded.

The Department, on behalf of the SWP, planned a five-year demonstration program of cloud-seeding in the upper Middle Fork Feather River basin, beginning in the 1991-92 season.

The program was to test the use of liquid propane injected into the clouds from generators on a mountain top. The test program was terminated after three years due to institutional difficulties.

A 1993 USBR feasibility study for a cloud seeding program in the watersheds above Shasta and Trinity dams indicated potential for the Trinity River Basin, but the study cast doubt about the effectiveness of a project for Shasta Lake. The Bureau had proposed a cloud seeding demonstration program in the upper Colorado River Basin, but the demonstration program was opposed by the State of Colorado. Presently, the Bureau is phasing out its participation in weather modification projects.

Cloud seeding is more successful in near-normal water years, when moisture in the form of storm clouds is present to be treated. It is also more effective when combined with carryover storage to take full advantage of additional precipitation and runoff. Institutional issues associated with cloud seeding programs include claims from third parties who allege damage from flooding or high water caused by the cloud seeding program. Because of the many legal and institutional difficulties associated with the third party impacts associated with weather modification, new cloud seeding projects are deferred from further consideration in this Bulletin.

Monterey County Water Resources Agency's Cloud Seeding Program

MCWRA initiated a cloud seeding program in 1990 to reduce the effects of the 1987-1992 drought and has continued the program as a cost-effective way to augment water supplies. The cost of the water gained in the reservoirs is less than $10 per af, according to MCWRA. In addition to airborne seeding, an experimental ground based propane dispenser was installed for rainfall enhancement in 1991. The program was designed to increase rainfall and subsequent runoff in the watershed of Arroyo Seco (a small undammed tributary of the Salinas River) and in San Antonio and Nacimiento reservoirs.

Monterey County relies solely on groundwater and local surface supplies, and faces chronic groundwater overdraft and seawater intrusion. The area's semiarid, Mediterranean-style climate provides only marginally sufficient rainfall during average years to sustain reservoir releases for aquifer recharge during the summer months. Furthermore, the occurrence interval and typical productivity of weather systems passing over the central coast are such that soil mass only reaches saturation near the end of the rain event, and the weather system moves on prior to the occurrence of substantial runoff. Cloud seeding, in most cases, provides additional rainfall that converts directly into runoff.

The typical interval for cloud seeding in Monterey County is from November 1 through the end of March. The primary target area is the 650 square miles of combined watershed above the Nacimiento and San Antonio reservoirs. To the north, the Arroyo Seco watershed, containing 240 square miles, is a secondary target area. Seeding flights in the early part of the water year seed the entire area, essentially affecting the reservoir drainage areas and Arroyo Seco. This early seeding provides additional runoff to the reservoir system as well as added groundwater recharge in the Arroyo Seco drainage area. Later in the water year, when the flows in the Arroyo Seco have reached the confluence with the Salinas River, flights are rerouted to concentrate the seeding effect on the reservoirs.

The five-year program has experienced varying degrees of success in terms of providing additional water supply. Usually, the wetter the storms, the greater the moisture available for conversion to precipitation and the more productive the seeding. Overall, evaluations show that rainfall increased about twenty percent above normal for the five-year study period. According to MCWRA, no known adverse environmental effect has occurred as a result of the project.

Other Supply Augmentation Options

This section discusses several other methods to augment water supplies. These options are conceptual, or have not yet been widely practiced. Hence, they are deferred from further evaluation in this Bulletin, but may be reconsidered in the future.

Water Bags

In 1996, a privately developed water bag delivery system was tested on a pilot scale when two bags each containing 2.4 af of water and linked together by zippers were towed from Port Angeles, Washington, to Seattle. Some problems emerged in the test run. These bags float because freshwater is lighter than saltwater. Costs associated with this option include towing costs, and cost of constructing, operating and maintaining the loading/unloading docks and pumps that would transfer the bagged water ashore to local treatment and distribution systems.

Gray Water

For the homeowner, some wastewater can be directly reused as gray water (such as used household water). Gray water can be used in subsurface systems to irrigate lawns, fruit trees, ornamental trees and shrubs and flowers (in finite amounts, depending on the plant types being irrigated). Water from the bathroom sink, washing machine, bathtub, or shower is generally safe to reuse. Care must be taken so that people and pets do not come in contact with gray water, and any food irrigated by gray water subsurface systems should be rinsed and cooked before being eaten.

Gray water has been used by some homeowners in coastal urban areas during extreme drought to save their landscaping. In the past, health concerns and lack of information limited use of gray water. In 1992, the Legislature amended the Water Code to allow gray water systems in residential buildings subject to appropriate standards and with the approval of local jurisdictions. There appears to be limited interest in exploring gray water as an option beyond listing its use as a potential urban BMP.

Watershed Management on National Forest Lands

National forest lands provide half of the streamflow runoff in the State. It has been suggested that if national forest management plans developed during the 1980s had been in place prior to 1982, the average runoff from national forests would have been increased by about 290,000 af (an increase of nearly 1 percent). Forest management proposals prepared on behalf of the biomass power industry call for forest management in the form of removing excess dead material and invasive species from the forest understory and thinning of the trees themselves. In this way, the proponents hope to return the forests to their pre-fire exclusion condition and achieve major wildfire reduction, and wildlife and water benefits. The thinning would also produce fuel for the biomass-energy industry. From a water supply perspective, extensive areas of land would have to be managed to increase statewide water supplies, requiring detailed consideration of potential environmental impacts.

Long-Range Weather Forecasting

Accurate advance weather information -- extending weeks, months, and even seasons ahead -- would be invaluable for planning all types of water operations. Had it been known, for instance, that 1976 and 1977 were going to be extremely dry years, or that the drought would end in 1977, water operations could have been planned somewhat differently and the impacts of the drought could have been lessened. The response to the 1987-92 drought might have been improved by storing more water in the winter of 1986-87, pursuant to a forecast, and using more of the remaining reserves in 1992, the last year of the drought.

The potential benefits of dependable long-range weather forecasts could be calculated in hundreds of millions of dollars, and their value would be national. Hence, research programs to investigate and develop forecasting capability would most appropriately be conducted at the national level. The National Weather Service routinely issues 30 and 90 day forecasts, and the Scripps Institution of Oceanography in San Diego (until recently), and Creighton University in Omaha, Nebraska, make experimental forecasts. The predictions have not been sufficiently reliable for water project operation. These may be improved by research on global weather patterns, including the El Niño-Southern Oscillation in the eastern Pacific Ocean.

Options for Future Environmental Habitat Enhancement

There are a number of programs in various stages of implementation designed to restore and/or enhance fish, water and related wildlife and wetland resources throughout the State. These programs vary in scope and geographic region, and objectives. Some of these programs include providing additional water supplies, while others involve structural measures, such as placing spawning gravel or constructing fish screens. Some of these programs are legislatively driven, while others have resulted from collaborative efforts among stakeholders. Table 6-21 illustrates the emphasis now being placed on environmental restoration actions, by identifying the variety of funding sources now available for fishery-related environmental restoration actions.

Table 6-21. Environmental Restoration Funding

Program Name Responsible Agencies	Projects/Program Funded Selection Criteria	Authorizing Legislation or Agreement	Funding Source	Funding Allocation
Program Name: Central Valley Project Improvement Act Anadromous Fish Restoration Program **Responsible Agencies:** USBR and USFWS	**Projects/Program Funded:** This program funds environmental restoration actions contributing to the goal of doubling natural production of anadromous fish in Central Valley rivers and streams. The program gives first priority to measures which protect and restore natural channel and riparian habitat values through habitat restoration actions; augment river and stream flows; and implement supporting measures mandated by CVPIA Section 3406(b). **Selection Criteria:** None specified in statute	Central Valley Project Improvement Act of 1992	Congressional appropriations from CVPIA Restoration Fund and Energy and Water Development Fund	Varies (actual expenditures: federal FY 1995, \$791,718; FY 1996 \$1,433,605
Program Name: CVPIA (state cost- sharing program) **Responsible Agencies:** DWR and DFG, in coordination with USBR and USFWS	**Projects/Program Funded:** This program funds environmental restoration projects with mandatory state cost-sharing under CVPIA Section 3406. Projects include the Shasta Dam temperature control device, Red Bluff Diversion Dam fish passage actions, spawning gravel restoration projects, and constructing fish screens. **Selection Criteria:** Projects must be capital outlay actions with mandatory state cost-sharing under CVPIA. California and the United States have executed a master cost-sharing agreement covering crediting and transferring funds for the restoration actions. Individual projects are credited pursuant to task order agreements executed in accordance with the master cost-sharing agreement.	• CVPIA • Prop. 204 • State-federal cost-sharing agreement, dated 06/27/94	General Obligation Bonds	\$93 million
Program Name: Category III Program **Responsible Agencies:** Agreement Signatories	**Projects/Program Funded:** Nonflow related projects to protect and improve Bay-Delta ecological resources. **Selection Criteria:** Selection is based on RFP process, with review by CALFED's Ecosystem Restoration Common Program.	1995 Bay-Delta Accord	Proposition 204, local water agency contributions, federal appropriations	State of California: \$60 million from Prop. 204; Local Agencies, see detail in footnote; federal government: matching funds depending upon congressional appropriations[1]

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Table 6-21. Environmental Restoration Funding

Program Name Responsible Agencies	Projects/Program Funded Selection Criteria	Authorizing Legislation or Agreement	Funding Source	Funding Allocation
Program Name: CALFED Ecosystem Restoration Program **Responsible Agencies:** CALFED member agencies	**Projects/Program Funded:** To be determined, but could include fish screens and spawning gravel restoration projects, and riparian habitat enhancement projects. **Selection Criteria:** To be determined.	Proposition 204	General Obligation Bonds	$390 million[2]
Program Name: Delta Pumping Plant Fish Protection Agreement (Four-Pumps Agreement) **Responsible Agencies:** DWR and DFG	**Projects/Program Funded:** Fish screens, rearing striped bass, gravel restoration projects, hatchery and other actions to benefit aquatic resources, particularly salmon and striped bass. Geographic scope includes the Central Valley and the Delta. **Selection Criteria:** Actions that benefit aquatic resources, particularly chinook salmon, steelhead and striped bass generally. Priority will be given to measures on the San Joaquin River system. DWR and DFG staff review project proposals and submit them to the 4-Pumps Fish Advisory Committee composed of representatives from the State Water Contractors, and the environmental and fishing communities. Recommendations from staff and the advisory committee are presented to the directors of DWR and DFG for approval.	Agreement Between the Department of Water Resources and Department of Fish and Game to Offset Direct Fish Losses in Relation to the Harvey O. Banks Delta Pumping Plant, 12/30/86	State Water Project funds administered by DWR	$15 million for fish population recovery program, and additional annual funding to compensate for annual fish losses caused by the Banks Pumping Plant[3]
Program Name: Tracy Fish Agreement **Responsible Agencies:** USBR and DFG	**Projects/Program Funded:** This agreement between DFG and USBR implements measures to reduce, offset, or replace direct losses of chinook salmon and striped bass in the Delta as a result of Tracy Pumping Plant diversions. **Selection Criteria:** A committee composed of representatives from USBR, DFG, and USFWS screens project proposals. Projects are funded upon recommendation by DFG Director to USBR.	Tracy Fish Agreement between U. S. Bureau of Reclamation and California Department of Fish and Game, dated June 1992	Congressional appropriations for operations and maintenance of CVP, administered by U.S. Bureau of Reclamation	Approximately $1 million a year. USBR has provided funding totaling $6.51 million during 1992-1997

Table 6-21. Environmental Restoration Funding

Program Name Responsible Agencies	Projects/Program Funded Selection Criteria	Authorizing Legislation or Agreement	Funding Source	Funding Allocation
Program Name: Commercial Salmon Stamp Account **Responsible Agency:** DFG	**Projects/Program Funded:** Projects to restore salmon populations through habitat restoration and breeding, and projects which provide public education on the importance and biology of salmon. Examples of eligible restoration projects include spawning gravel restoration, bank stabilization to prevent siltation in streams, riparian revegetation, barrier modification to improve fish passage, installation of fish ladders and screens, and short-term salmon breeding. **Selection Criteria:** Projects are evaluated based on benefits to fishery resources, need for work in a particular watershed for target species, and project costs. Project proposals are evaluated and prioritized first by DFG staff. Projects for salmon habitat restoration and breeding considered for funding are sent to the Commercial Salmon Trollers Advisory Committee. There are two subaccounts in the program, (1) Commercial Salmon Stamp Dedicated Account, and (2) Augmented Salmon Stamp Dedicated Account. The Commercial Salmon Stamp Dedicated Account is statutorily directed to salmon breeding. Expenditures from the Augmented Salmon Stamp Dedicated Account must meet the recommendations of the Commercial Salmon Trollers Advisory Committee. Projects for salmon habitat restoration may also be funded under Proposition 70. Final funding decision is by the Director of DFG.	Fish and Game Code Sections 7860 - 7863 that impose a stamp fee on commercial salmon fishers, as well as commercial passenger salmon fishing vessel operators	Annual stamp fee which ranges from $85 to $260 depending on salmon landing	Total annual revenue varies from $340,000 to just over $1 million. Up to $500,000 may be available in state FY 1996-97
Program Name: California Wildlife, Coastal and Park Land Conservation Initiative (Proposition 70) **Responsible Agency:** DFG	**Projects/Program Funded:** Projects to restore and enhance salmon streams, and wild trout and native steelhead habitat. **Selection Criteria:** The evaluation process considers the benefits to fishery resources, the need for work in a particular watershed for the target species, and project costs. Project proposals are initially reviewed by DFG and then sent to the Commercial Salmon Trollers Advisory Committee and to the Proposition 70 Subcommittee (a six-member group representing the Commercial Salmon Trollers Advisory Committee and the California Advisory Committee on Salmon and Steelhead Trout) for funding consideration. Final approval for funding is by the Director of DFG	Proposition 70 of 1988	General Obligation Bonds[4]	Up to $1.3 million will be available from Prop. 70 during FY 1996-97

Table 6-21. Environmental Restoration Funding

Program Name Responsible Agencies	Projects/Program Funded Selection Criteria	Authorizing Legislation or Agreement	Funding Source	Funding Allocation

[1] State of California: $60 million from Proposition 204; local agencies: $30 million pledge by MWDSC for 3 years (MWDSC has already given $20 million and plans to give the remaining $10 million); one time contributions from include following, (1) Santa Clara Valley Water District $500,000, (2) East Bay Municipal Utility District $500,000, (3) Alameda County Water District $100,000, (4) San Francisco Public Utilities Commission $500,000, and Contra Costa Water District $100,000; and federal government: matching funds depending on congressional appropriations.

[2] This money is not available until a programmatic EIR/EIS is completed and a state-federal cost sharing agreement is implemented. The programmatic EIR/EIS is scheduled to be completed in late 1998.

[3] Generally, the $15 million funds projects with long-term benefits to fish, while the annual account funds projects to replace fish lost annually at the pumping plant. By 1996, DWR had allocated all of the $15 million and had spent about $6 million in annual mitigation projects.

[4] State FY 1997-98 is the last year of funding under Proposition 70. DFG received $10 million to restore and enhance salmon streams, and $6 million to restore and enhance wild trout and native steelhead habitat and related projects.

This section identifies and describes programs expected to provide future environmental benefits. This section covers a representative sample, and is not meant to be a comprehensive listing of all possibilities statewide. The summary table at the end of the section delineates structural habitat improvement projects, instream flow and Delta flow augmentation projects, and wetlands programs.

The Central Valley Project Improvement Act

The following section provides an overview of expected future work on some of the environmental restoration actions authorized in the act, focusing on actions such as water acquisition and fish screening which are applicable to the entire Central Valley. Site-specific projects such as construction of the Shasta Dam TCD are described in Chapters 7 through 9 .

Anadromous Fish Restoration Program.

The May 1997 draft AFRP plan proposed habitat restoration actions such as spawning gravel placement and stream channel restoration, acquisition of land for wildlife habitat, construction of fish screens and facilities to improve passage of migrating anadromous fish, and development of plans to prevent habitat degradation because of sedimentation and urbanization. It also included target instream flows for rivers and streams in the Central Valley and the Delta. The three tools available for the Department of Interior to use to meet these flow objectives are reoperation of the CVP, dedication and management of 800,000 af of CVP yield annually, and water acquisition. Tools available to meet CVPIA's broad goal of doubling anadromous fish populations in the Central Valley include the many physical habitat restoration actions specified in the act, as well as substantial funding from the CVPIA restoration fund and from general congressional appropriations. As described in the environmental water use section of Chapter 4, the Department has included representative future water demands from the AFRP in the 2020 forecast of environmental water use. USBR and USFWS would acquire supplemental fishery water (and water for full habitat development at wildlife refuges) via the longer-term program planned to replace the interim program described earlier in this chapter.

Anadromous Fish Screen Program.

Under this program, USBR and USFWS have contributed funding for local agency and privately owned fish screen installation projects, as well as for planning studies. Examples of completed and pending projects were described in Chapter 5.

Spawning Gravel/Riparian Habitat Restoration Program.

To date, USBR and USFWS have completed two spawning gravel replenishment projects on the Sacramento River below Keswick Dam. Additional projects are being planned for the Sacramento and the other authorized rivers. This program is analogous to an on-going operations and maintenance program, where work would be done periodically on river segments identified as needing gravel replenishment. A monitoring program would be required, both to identify areas that are gravel-limited, and to evaluate the effectiveness of the gravel provided.

1994 Bay-Delta Agreement

Category III Program.

As part of the 1994 Bay-Delta Accord, a special funding program, Category III, was established to address nonflow factors affecting the health of the Bay-Delta ecosystem. A Category III Steering Committee, consisting of agricultural, urban and environmental stakeholders administered the project selection process, resulting in 32 restoration projects funded in 1995 and 1996. The projects approved for funding included land acquisitions, fish screens, habitat restoration, and toxicity study for a total up to $21.5 million. Table 6-22 shows Projects funded to date.

Table 6-22. Bay-Delta Category III Projects Funded to Date

Project / Program	*Proponent*	*Category III Funds*
Battle Creek Restoration	Department of Fish and Game	$730,000
Durham Mutual Fish Screen and Fish Ladder	Durham Mutual Water Company	up to $416,500
M&T/Parrott Pump Relocation and Fish Screen	Ducks Unlimited, Inc.	$1,550,000
Biologically Integrated Orchard Systems Program	Comm. Alliance w/ Family Farmers Fnd.	$660,000
Sac. River Habitat Restoration (Colusa to Verona)	Wildlife Conservation Board	$400,000
Suisun Marsh Screening Project	Suisun Resources Conservation Dist.	up to $950,000
Sac. River Winter-Run Broodstock Program	Pacific Coast Fed. of Fishermen's Assoc.	$300,000
Western Canal Water District Butte Creek Siphon	Western Canal Water District	$2,739,000
Prospect Island Restoration	Department of Water Resources	up to $2,535,000
Sac. R. Habitat Restoration (Verona to Collinsville)	DWR/The Reclamation Board	$500,000
Princeton Pumping Plant Fish Screens	Reclamation District 1004	$75,000
Princeton-Codora-Glenn/Provident ID Fish Screen	PCGID/PID	$5,575,000
Cosumnes River Preserve (Valensin Acquisition)	The Nature Conservancy	$1,500,000
Lower Butte Creek Habitat Restoration	The Nature Conservancy	$130,000
Sherman Island Levee Habitat Demonstration	Department of Water Resources	up to $480,000
Ecological Functions of Restored Wetlands in the Delta	University of Washington	$475,000
Molecular Genetic Identification of Chinook Salmon Runs, Focused on Spring-Run Integrity	Bodega Marine Laboratory	$450,000
Decker Island Tidal Wetland Enhancement	Port of Sacramento	$399,000
Yolo Bypass Habitat Restoration Study	Department of Fish and Game	$226,000
Clear Creek Property Acquisition Assistance	Bureau of Land Management	up to $211,000
Research Program to Address the Introduction of Non-Indigenous Aquatic Species	San Francisco Estuary Institute	$197,000
Sac. River and Major Tributaries Corridor Mapping	University of California, Chico	$145,200
Fish Screen for Unscreened Diversion on Yuba R.	Browns Valley Irrigation District	$114,750
Effects of Toxics on Central Valley Chinook Salmon	Fox Environmental Management	$110,000
Barrier Intake Screen at Wilkins Slough Diversions	Reclamation District 108	$100,000
San Joaquin River to Main Lift Canal Intake Channel Fish Screen Facility	Banta-Carbona Irrigation District	$100,000
Adams Dam Fish Screen and Fish Ladder	Rancho Esquon Partners	up to $100,000
Gorrill Dam Fish Screen and Fish Ladder	Gorrill Land Company	up to $100,000
Testing of Fish Screen for Small Unscreened Diver.	Buell and Associates	$90,000
Watershed Management Strategy for Butte Creek	University of California, Chico	$83,000
Establish Battle Creek Watershed Conservancy	Western Shasta Resource Consv. Dist.	$50,000
Inventory of Rearing Habitat for Juvenile Salmon	Calif. State University, Sacramento	$24,500
	TOTAL	***$21,515,950***

In 1997 CALFED became the lead agency for implementing the Category III program. Funding sources for the program consist of $10 million from stakeholders and $60 million from Proposition 204 funding. The Ecosystem Roundtable, a subcommittee of the Bay-Delta Advisory Council, provides stakeholder input on CALFED ecosystem restoration projects, as well as priorities for near-term restoration and selection of Category III projects.

In June 1997, Request for Proposals were distributed to solicit projects to be funded with the $70 million. To determine which proposals would be funded, 13 technical review panels made up of State, federal, and local expects, were established, each addressing a particular area of restoration (i.e., wetlands, gravel, fish screens). Evaluation results were forwarded to the Integration Panel which consist of 18 State, federal, and non-agency technical representatives. The panel will then identify the package of projects and programs that will comprise the 1997 Category III funding recommendation. Funding recommendations will be coordinated with appropriate other funding sources (e.g., CVPIA) and programs through other agencies such as EPA and SWRCB. After the Integration Panel recommendations are reviewed by the Ecosystem Roundtable and BDAC, the CALFED Policy Group, the decision making body of CALFED, will make final approvals.

One example of a project that was provided with Category III funding is the Prospect Island restoration project, a pilot Delta shallow water habitat project sponsored by the Department and the Corps. Prospect Island, located in Solano County in the northwestern part of the Delta, covers approximately 1,600 acres, with the restoration project amounting to almost 1,300 acres of that total.

The project's objectives are to create wetland habitat, restore fish and wildlife habitat, create shaded riverine aquatic habitat, and decrease maintenance costs on the Sacramento Deepwater Ship Channel levee. Most of the 1,300-acre project area had been in agricultural land use with crops such as corn, safflower, sugar beets, and wheat. The project includes flooding the interior of Prospect Island to create internal islands in the flooded area, stabilizing the existing levees by flattening the slopes, and stabilizing the levees and internal islands with erosion control plantings. The Ship Channel and Miner Slough levees will be breached in one location each, restoring full tidal action to the site.

The USACE is the federal sponsor of the project under WRDA Section 1135 authority and the Department is the nonfederal sponsor, with funding support from Category III. USBR purchased the 1,300 acre site with CVPIA funds in 1995. After restoration is completed, USFWS will manage the property in conjunction with the nearby Stone Lakes Refuge. Category III has established an endowment fund of $1.25 million for the long-term maintenance of the project.

CALFED Bay-Delta Ecosystem Restoration Program

CALFED's Ecosystem Restoration Program Plan is to provide the foundation for a long-term ecosystem restoration effort that may take several decades to implement. The ERPP will be included in each of the alternatives being evaluated in the Programmatic EIR/EIS. The Draft ERPP was circulated for review in mid-1997. Some proposed actions contained in the plan include:

- Breeching levees for intertidal wetlands
- Constructing setback levees to increase floodplain and riparian corridors
- Limiting further subsidence of Delta islands by implementing measures such as restoring wetlands to halt the loss of peat soil.
- Controlling introduced species and reducing the probability of additional introductions.
- Acquiring land or water from willing sellers for ecosystem improvements.
- Providing incentives to encourage environmentally friendly agricultural practices.

Congress authorized $430 million over the next 3 years for the federal share of CALFED programs such as Category III and initial implementation of the ERPP, and appropriated $85 million for federal fiscal year 1998. Proposition 204 also included $390 million for implementation of the ERPP; however, this funding will not be available until after CALFED's PEIR/EIS has been completed.

Other Environmental Enhancement Options

Sherman and Twitchell Islands Wildlife Management Plans.

The objective of both management plans is to implement land use management programs that effectively control subsidence and soil erosion on Twitchell and Sherman Islands, while also providing significant wetland and riparian habitat for wildlife. The plans are designed to benefit wildlife species that occupy wetland, upland, and riparian habitat, and provide recreational opportunities such as walking trails and wildlife viewing. Subsidence would be reduced by minimizing oxidation and erosion of the peat soils on the islands, by replacing present agricultural cultivation practices with land use management practices designed to stabilize the soil. Such practices range from minimizing tillage to establishing wetland habitat.

Altering land use practices on Twitchell Island could provide up to 3,000 acres of wetland and riparian habitat managed for wildlife, flood control benefits, more protection of Delta water quality and supply reliability, and more recreational opportunities in the Delta.

Fish Protection Agreements.

To mitigate fish losses at Delta export facilities, both the SWP and CVP have entered into agreements with DFG. Subsequent to execution of USBR's agreement with DFG, CVPIA directed USBR to substantially upgrade Tracy Pumping Plant's fish protection facilities, even to the extent of constructing a new screening facility. Planning studies are now under way for a major upgrade of the existing facility. The Department's four-pumps agreement with DFG has funded, or cost-shared, in many habitat restoration actions upstream of the Delta since its inception, as noted in Chapter 2. Discussions are presently ongoing regarding the possibility of using the remainder of the agreement's capital outlay funds to construct a fish hatchery on the Tuolumne River.

Upper Sacramento River Fisheries and Riparian Habitat Restoration Program (SB 1086).

As described in Chapter 2, elements of the 1989 plan prepared by this program were incorporated in CVPIA, or are being considered in forums such as the CALFED Bay-Delta program. In 1992 the Resources Agency reconvened the SB 1086 Advisory Council. The council's current charge is two-part: (1) to serve in an advisory capacity to State agencies responsible for those portions of the CVPIA that are likely to affect the Upper Sacramento River and adjacent lands, and (2) to complete the Council's earlier work concerning riparian habitat protection and management. The goals for the latter item include establishing a riparian habitat management area and a governance or management entity for the area. Recommendations are being developed for the boundaries of a riparian habitat conservation area, management objectives by river reach, and the type of governance organization that could most effectively carry out the management plan.

Financing Local Water Management Options

Many of the options discussed in the Bulletin will require a large commitment of funds and other resources to implement and maintain them over time. When a local agency is confronted with additional expenditures for water management options, it must decide whether the costs of these options will be paid from current or accumulated revenues (pay-as-you-go), or be financed with the proceeds of debt repaid from future revenues. Although this financial commitment is a challenge for all levels of government, it is especially critical for local water agencies, which find it increasingly difficult to finance water system improvements. Historically, local water agencies relied upon a number of conventional methods for long-term debt financing, including general obligation bonds, revenue bonds, and assessment bonds. However, innovative long-term debt financing strategies, such as bond pools, are being increasingly used.

Financial costs are different from economic costs. Financial costs are the actual expenditures, required by a water agency to repay the debt (with interest) incurred to finance the capital costs of an option and to meet operations and maintenance costs. Thus, the objective of financial feasibility studies is to solve "cash flow" problems. In contrast, economic costs reflect the costs of committing resources needed to construct, operate and maintain an option for life, to whomever they may accrue. Economic feasibility studies are used to compare the relative merit of options, to determine the most economically efficient size or configuration of an option, and to allocate costs among beneficiaries. It is possible for options to be financially feasible and economically unjustified, or vice versa. For example, even though an agency can generate the funds to pay for an option, this does not necessarily mean that the option is economically the best of available options. On the other hand, an option may be economically justified but it cannot be financed because of existing debt limitations.

Financial feasibility is becoming an increasingly important consideration in water supply management planning for a number of reasons:

- Annual statewide demands are expected to exceed available water supplies. Thus there is a need to develop water supply augmentation and demand management programs;
- Compliance with new EPA and DHS drinking water standards is likely to increase capital expenditures by municipal water agencies;

- Some water suppliers have deferred maintenance and/or replacement of aging facilities to the point where they are beginning to experience significantly increased operation, maintenance and replacement costs;
- Since the 1980s the federal government has been reducing aid to state and local governments for large-scale water resources projects, a trend which is expected to continue;
- Since the early 1990s, the California Legislature has been shifting property tax revenues away from counties and special districts and into the State's general fund.

Sources of Revenues

Whether capital improvements are funded on a pay-as-you-go basis or through debt financing, the water agency must have sufficient revenues to cover capital costs as well as ongoing operation and maintenance costs. The major sources of revenue for publicly-owned systems include water rates charged to customers, property taxes (although use of these has been limited since passage of Proposition 13), and benefit assessments through special improvement districts. Because of voter opposition to further tax increases, local governments have increasingly relied upon other revenue sources such as development impact fees from new construction, standby fees, and fees for special services. These alternatives are typically only feasible for agencies with large service areas, so that income from these fees will be significant and reliable. Private investor-owned water agencies and mutual water companies are almost exclusively dependent upon water rates to generate revenues. Tables 6-23 and 6-24 show significant sources of revenue for water agencies by type of ownership and by agency size.

Financing Methods

The ability of a local public agency to access different financing methods depends upon the enabling legislation under which the agency was formed. Among other things, the enabling legislation will indicate the agency's:

- authority to issue bonds (including general obligation bonds and revenue bonds), the vote required to authorize issuance, and any limitations on the amounts of bonds or on the amount of indebtedness;
- powers and methods of tax assessments, including whether the assessments are on an ad valorem basis (a tax based on value of property) or are levied according to benefits, and

the type of property (land and/or improvements) upon which the assessments may be levied;

- revenue sources, including charges, rates or tolls for service or commodities or sales and leases of property, etc.;
- the area over which the agency can collect taxes and/or sell services or commodities.

Table 6-23. Significant Sources of Revenue to Water Agencies by Type of Ownership

Revenue Source	*Publicly-Owned*	*Investor-Owned*	*Mutual*
Water Rates	X	X	X
Property Taxes	X		
Special Improvement District Assessments	X		
Development Impact Fees	X		
Customer Hookup Fees	X		
Special Service Fees	X	X	

Source: California Department of Health Services. *Drinking Water into the 21st Century*. January 1993.

Table 6-24. Significant Sources of Revenue to Water Agencies by Water Agency Size

Revenue Sources	*Small*	*Intermediate*	*Medium*	*Large*
Water Rates	X	X	X	X
Property Taxes		X	X	X
Special Improvement District Assessments		X	X	X
Development Impact Fees				X
Customer Hookup Fees				X
Special Service Fees				X

Source: California Department of Health Services. *Drinking Water into the 21st Century*. January 1993.

Self-Financing.

Self-financing, or pay-as-you-go, is a form of non-debt financing. A water agency can use reserves generated from accumulated revenues and other income to pay for improvements rather than incurring debt. The pay-as-you-go approach generally works best for small or recurring capital expenditures that can be reasonably accommodated in an agency's annual budget. However, for major capital improvements, a debt financing approach would be more appropriate.

Short-Term Debt Financing.

Short-term debt financing typically includes short-term borrowing instruments with maturities of less than 1 year. Short-term borrowing can be used for cash flow borrowing, financing for capital improvements with relatively short lives, and interim financing for long-term capital improvements:

- *Cash Flow Borrowing.* Revenue and tax anticipation notes can be used when an agency is experiencing cash flow problems because revenues (from charges or taxes) are occurring unevenly during the fiscal year. Revenue and tax anticipation notes can be used to pay current expenses, with note repayment coming from revenues received later in the fiscal year.
- *Financing for Short-Lived Capital Assets.* Capital items with relatively short lives can be financed through the use of commercial paper, which are short-term, unsecured promissory notes backed by a line of credit from one or more banks.
- *Interim Long-term Financing.* Short-term financing methods can provide interim financing for the construction of capital improvements which are anticipated to be financed on a permanent basis at a later date. Examples of interim financing include grant anticipation notes (where the permanent funding could be a grant from another government agency) and bond anticipation notes (where the permanent funding will come through the issuance of long term debt such as bonds).

Conventional Long-term Debt Financing.

Conventional long-term debt financing methods include general obligation bonds, revenue bonds, assessment bonds, and lease or installment sales agreements, all of which are typically used by publicly-owned utilities:

- *General Obligation Bonds.* These bonds are typically used to finance improvements benefitting the community as a whole, and they are secured by the full faith and credit of the agency. General obligation bonds issued by public water agencies are secured by a pledge of the agency's ad valorem taxing power (i.e., the power to tax property based upon its value). However, the passage of Proposition 13 (and its requirement for two-thirds voter approval) has limited the ability of agencies to assess additional property taxes which would be needed to fulfill this pledge, thereby reducing the use of these bonds. General obligation bond limits are often established by a water agency's enabling legislation.

- *Revenue Bonds*. These bonds do not require the agency's pledge of full faith and credit. Debt service for these bonds is paid exclusively from a specific revenue source, such as the revenue obtained from the operation of the financed project. Because revenue bonds do not require voter approval, they are now more commonly used than general obligation bonds.
- *Assessment Bonds.* These bonds are issued to finance capital improvements and debt service, and are paid through assessments levied upon real property benefitted by such improvements and are secured by a lien on that property. Under the Mello-Roos Community Facilities Act of 1982, water agencies may establish a Community Facilities District and levy a special tax upon land within that district. This tax can be used to finance capital improvements (generally distribution systems), new services or to repay bonds issued for such purposes. However, the passage of Proposition 218 in 1996 substantially changed the way in which property-related assessments can be imposed by local agencies. In the future, these assessments must be subjected to a vote of the property owners.
- *Lease or Installment Revenue Bonds.* Taxpayer resistance and state statutes (Proposition 13) have limited the taxing and borrowing ability of local agencies, thus reducing the use of general obligation bonds. As a result, lease revenue bonds have become common. In California, a form of a lease revenue bond is the Certificate of Participation. With a COP, facilities are built or acquired by an agency of the city, and leased to the city, for which the city makes lease payments equal to the principal repayment plus interest. Either a city non-profit corporation or a community redevelopment agency must be used as the intermediary leasing entity, but that agency must give the facilities to the city free and clear without added expense when the indebtedness is repaid.

Innovative Long-term Debt Financing.

New long-term debt financing strategies are being developed to assist water agencies to obtain funding for water system improvements. Two examples of these strategies are bond pools and privatization:

- *Bond Pools.* Bond pools increase access to bond funds for smaller water agencies which might not otherwise be able to obtain this type of funding. Bond pools require the use of a JPA to combine ("pool") several small bond offerings into a single financial package, thereby minimizing the cost of bond issuance for participating water agencies. The Association of California Water Agencies and the WateReuse Association offers such financial packages.
- *Privatization.* Privatization occurs when the private sector becomes involved in the design, financing, construction, ownership and/or operation of a public facility such as a water system improvement. Privatization can offer several advantages. For example, it may be cheaper and/or more available than other forms of financing and it also may provide substantial tax advantages to the private sector. When the publicly-owned water agency's access to the financial markets is diminished or nonexistent, such as is the case for many smaller utilities, privately arranged financing may be an attractive option. Although privatization has been used in other states, it is not common in California.
- *Water Transfers.* Another potential opportunity for water agencies (especially agricultural agencies) involves the transfer of water in exchange for water system improvements. An example is the negotiated agreement between the MWDSC and the IID, where the MWDSC is financing more than $200 million in IID system improvements in exchange for a 35-year right to approximately 106,000 af of water per year.

Credit Substitution and Enhancement.

Although not financing methods, credit substitution and enhancement can assist local agencies in obtaining financing and in lowering the costs of financing. Credit substitution occurs when an agency substitutes its own credit for that of a local agency that is seeking to finance a project. As a result, the local agency can improve the quality of its bonds and generally obtain them at a lower cost. Credit enhancement occurs when an agency guarantees that the debt service obligations will be met, which can be a low cost and effective way for states to assist local agencies.

State and Federal Financial Assistance Programs.

State and federal financial assistance programs (loans and grants) are available to water agencies. These programs target numerous objectives, including safe drinking water, water conservation, water recycling, and water supply development (for example, groundwater recharge projects). Each of these programs has established criteria to determine project eligibility and funding. Most of the state and federal programs do not provide funding to investor-owned and mutual companies because this is considered to be adding value to privately owned businesses. The 1996 Safe Drinking Water Act reauthorization may provide approximately $12.4 billion from 1997 through 2003 for current and new drinking water programs, including a State Revolving Fund of $1 billion per year nationally through 2003. Table 6-25 shows some of the major state and federal financial assistance programs available for water system improvements, along with the objectives of the programs and the agencies which administer them.

The passage of Proposition 204 (Safe, Clean, Reliable Water Supply Act) in November of 1996 authorized $995 million to be spent upon a variety of statewide water reliability/supply programs and environmental restoration. Some of these programs include grants to local agencies for a variety of purposes. For example, the Department will administer two programs that will provide loans (and in some cases, grants) to local agencies for water conservation/groundwater recharge facilities ($30 million) and local projects ($25 million). The SWRCB will also administer loans for water recycling, including $60 million for loans and grants for local feasibility studies and $30 million for grants to small communities for the construction of eligible treatment projects.

Table 6-25. Major State and Federal Financial Assistance Programs

Financial Assistance Programs	*Objectives*	*Administering Agencies*
State		
Safe Drinking Water Bond Laws	Grants/low interest loans for public water system improvements	Department of Water Resources/Department of Health Services
Water Conservation Bond Laws	Low interest loans for water conservation, groundwater recharge, local water supply, and water recycling projects	Department of Water Resources/State Water Resources Control Board
Agricultural Drainage Water Management Loan	Low interest loans for agricultural drainage projects	State Water Resources Control Board
Safe, Clean, Reliable Water Supply Act of 1996 (Proposition 204)	Low interest loans and grants for water conservation, groundwater recharge and water recycling projects	Department of Water Resources/State Water Resources Control Board
Federal		
Water and Waste Water Disposal Loans/Grants	Loans and grants to small communities for water and wastewater facilities	Farmers Home Administration
Community Development Block Grants (HUD)	Grants to large communities for water and wastewater facilities	Housing and Urban Development through Department of Housing & Community Develoment
Small Business Administration Loans	Loans for private water system improvements	Small Business Administration
Federal/State		
Clean Water Act SRF	Low interest loans for water recycling projects	State Water Resources Control Board
Safe Drinking Water Act SRF	Low interest loans for public water system improvements	Under development

Relationship Between Financing and Water Agency Ownership and Size

As mentioned above, the types of financing available can vary depending upon the ownership and size of the water agencies. These relationships are discussed below:

Public Water Agency.

In general, public water agencies have a greater availability of financing methods compared to private investor-owned and mutual water companies. Many long- and short-term financing instruments will be tax-exempt for publicly-owned agencies. The larger public agencies can issue tax-exempt notes and bonds, assess property taxes, issue special assessment bonds, and enter into public/private partnerships to finance capital improvements. A smaller public agency may be unable to secure these types of financing because either the cost of that method (such as the cost of issuing bonds) or the amount of funds needed to make improvements exceeds the ability of its customers to pay. In these cases, the smaller agencies need to either obtain federal and state assistance, if available, or pursue innovative financing methods. Local public agencies must limit their rates to amounts needed to cover current financing and water costs--they are not allowed to make a profit.

Investor-Owned Water System Financing.

Investor owned utilities are owned by an individual, partnership, corporation, or other entity. These utilities have the capability of issuing equity stock and selling taxable bonds of their company. The California Public Utilities Commission must give authorization prior to the issuance of any stocks or bonds of an investor-owned water company. This method of financing is primarily limited to the larger investor-owned systems. The smaller investor-owned agencies generally do not issue stock and may lack the rate base that would make other financial methods feasible. The CPUC establishes the return on investment that investor-owned utilities are allowed to earn as part of its rate setting authority. Regulated investor-owned agencies are not able to accumulate reserves. They may use both short-and long-term taxable bonds and notes.

Mutual Water Companies.

A mutual water company is a privately owned company that issues securities in which lot owners are entitled to one share for each lot they own. Mutual water companies have the ability to assess members to raise capital. This does not require the approval by either the members or an outside agency. The amount of the assessment may be limited, however, by the ability of the customers to pay. As a requirement of formation of a mutual water company, a sinking fund must be established that provides capital replacement of water facilities at the end of their useful life. Some of the larger mutual companies may be able to use short- and long-term financing instruments such as taxable bonds and notes.

Table 6-26. Financing Methods Available to Water Agencies by Type of Ownership

Financing Method	*Publicly-Owned*	*Investor-Owned*	*Mutual*
Self-Financing	X	X	X
Short-Term Financing			
Fixed Rate Notes	X	X[1]	X[1]
Commercial Paper	X	X[1]	X[1]
Floating Rate Demand Notes	X	X[1]	X[1]
Conventional Long-Term Financing			
Equity Shares or Stock		X	X
Bonds (GO and Revenue)	X	X[1]	X[1]
Lease Revenue	X		
Innovative Long-Term Financing			
Bond Pools	X		
Privatization	X		X
Water transfers	X	X	X
Financial Assistance Programs	X	X[2]	X[2]

[1] Taxable instruments.

[2] State and federal loan and grant programs have limited applications for private water agencies.

Source: California Department of Health Services. *Drinking Water into the 21st Century.* January 1993.

Tables 6-26 and 6-27 summarize types of financial methods available by ownership type and size of water districts. Tables 6-28 and 6-29 summarize financial assistance programs by ownership type and size of water districts.

Table 6-27. Financing Methods Available to Water Agencies by Water Agency Size

Financing Method	*Small*	*Inter-mediate*	*Medium*	*Large*
Self-Financing			X	X
Short-Term Financing				
Fixed Rate Notes				X
Commercial Paper				X
Floating Rate Demand Notes				X
Conventional Long-Term Financing				
Equity Shares or Stock			X	X
Bonds (GO and Revenue)				X
Lease Revenue Bonds				X
Innovative Long-Term Financing				
Bond Pools	X	X	X	X
Privatization	X	X	X	X
Water Transfers	X	X	X	X
Financial Assistance Programs	X[1]	X[1]	X[1]	X[1]

[1] State and federal loan and grant programs have limited applications for private water agencies--see Table 6-25

Source: California Department of Health Services. *Drinking Water into the 21st Century*. January 1993.

Table 6-28. Financial Assistance Programs Available to Water Agencies by Type of Ownership

Financial Assistance Programs & Administering Entity	*Publicly-Owned*	*Investor-Owned*	*Mutual*
State			
Safe Drinking Water Bond Laws	X	X(1)	X(1)
Water Conservation Bond Laws	X		
Agricultural Drainage Water Management Loans	X		
Community Development Block Grants	X		
State Revolving Fund for Wastewater	X		
State Revolving Fund for Drinking Water	X		
Federal			
Water and Waste Water Disposal Loans and Grants	X		X
Community Development Block Grants	X		
Small Business Administration Loans		X	

Source: California Department of Health Services. *Drinking Water into the 21st Century*. January 1993.
(1) Loans only; grants not provided to privately-owned agencies.

Table 6-29. Financial Assistance Programs Available to Water Agencies by Water Agency Size

Financial Assistance Programs	*Small*	*Intermediate*	*Medium*	*Large*
State				
Safe Drinking Water Bond Laws	X	X	X	X
Water Conservation Bond Laws	X	X	X	X
Agricultural Drainage Water Management Loans	X	X	X	X
Community Development Block Grants	X	X	X	
State Revolving Fund for Wastewater	X	X	X	X
State Revolving Fund for Drinking Water	X	X	X	X
Federal				
Water and Waste Water Disposal Loans and Grants	X	X	X	
Community Development Block Grants				X
Small Business Administration Loans	X	X	X	

Source: California Department of Health Services. *Drinking Water into the 21st Century*. January 1993.

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